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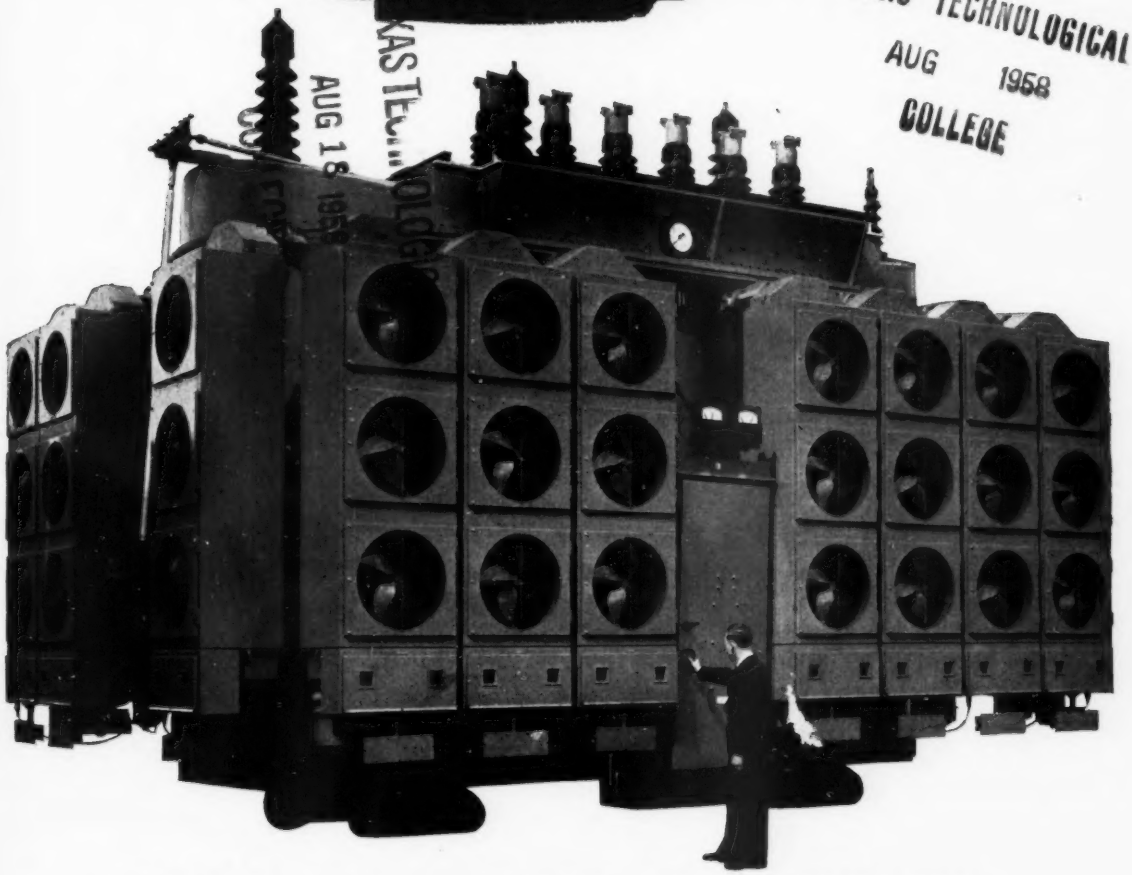

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breakers control and

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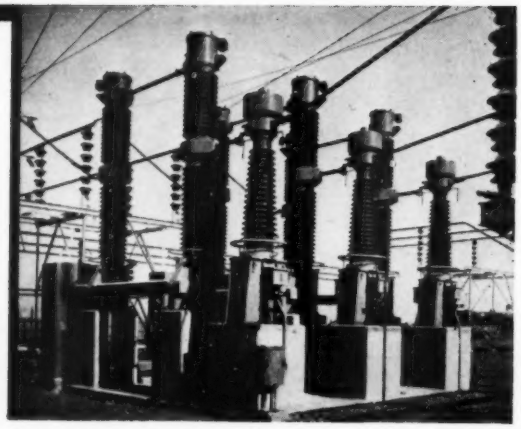


220-kV small-oil-volume circuit-breakers in Australia

—from generation

at the power-station

down to local distribution

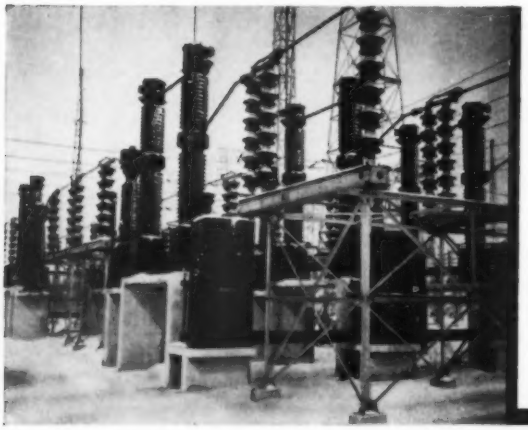
in the factory,

their reliability in service

has been proved

under every climatic condition

220-kV small-oil-volume circuit-breakers in Canada



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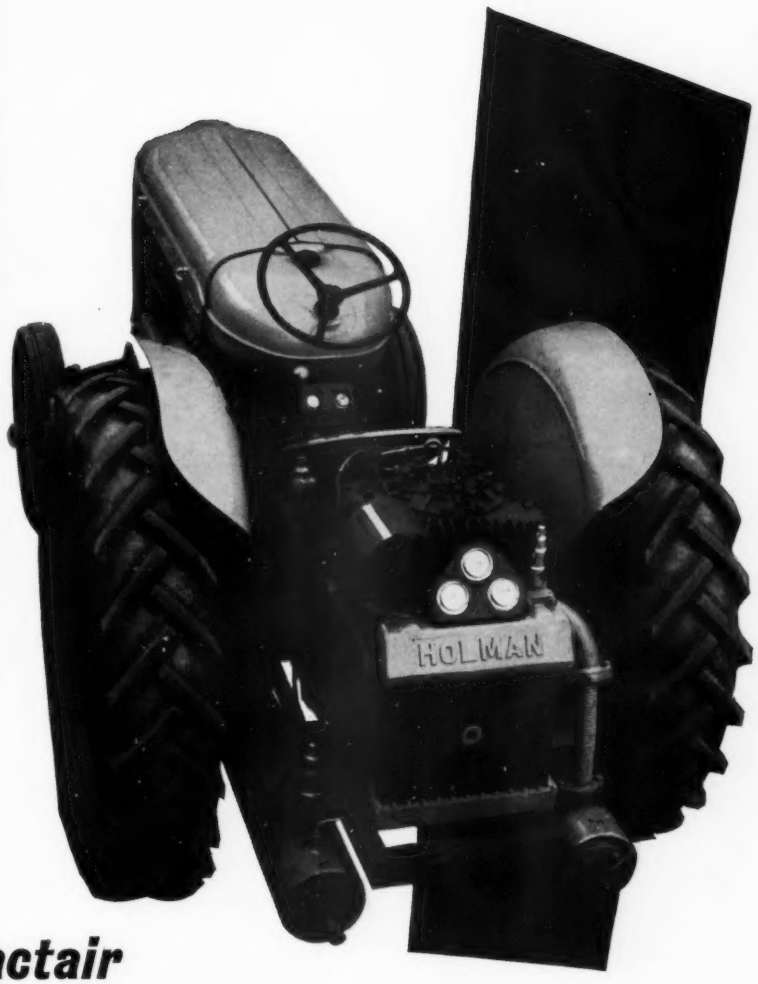

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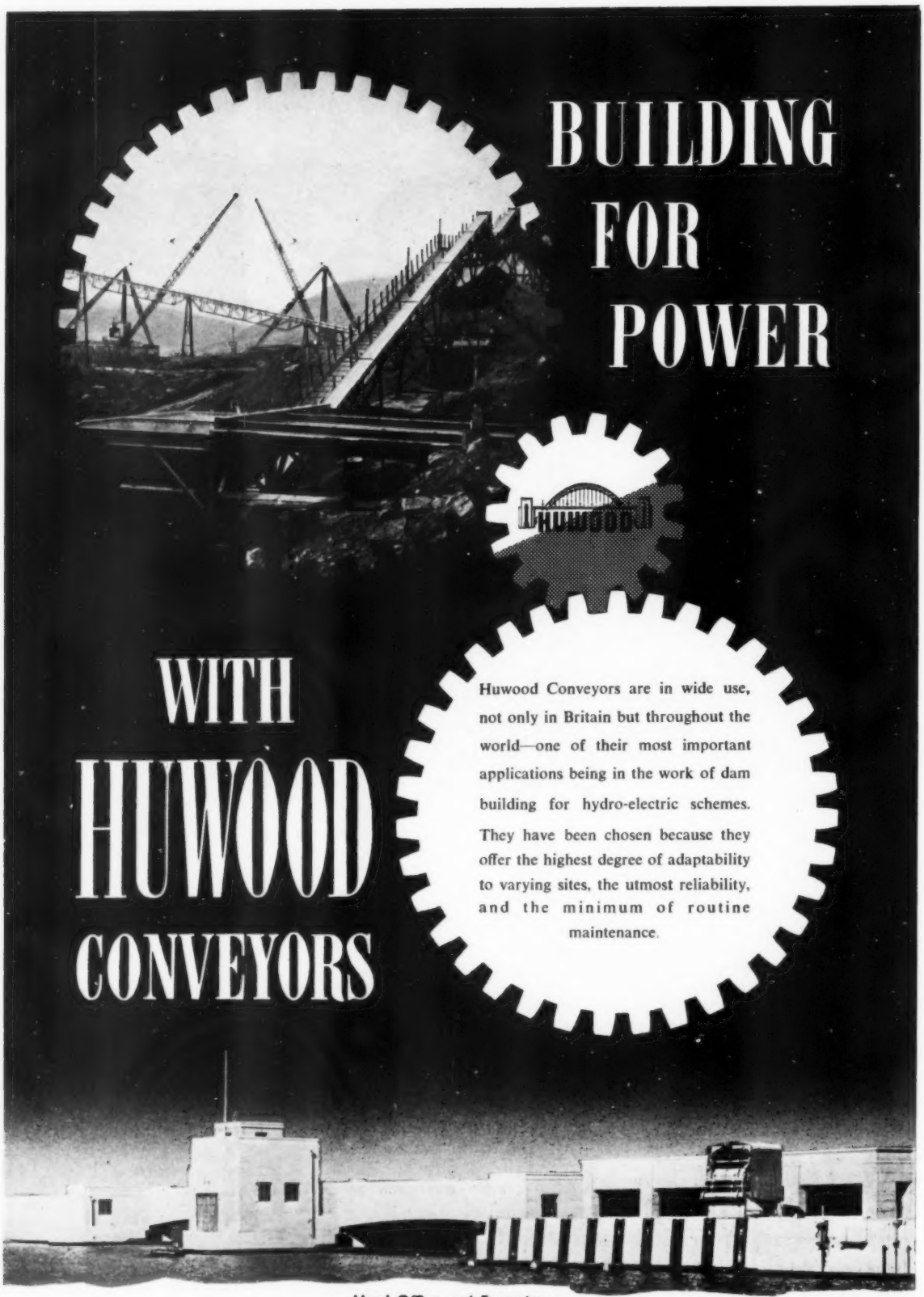
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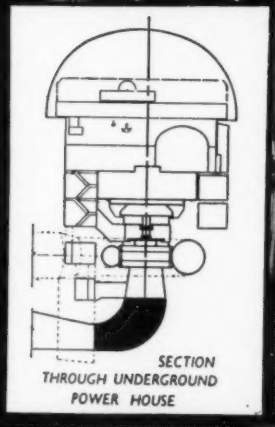

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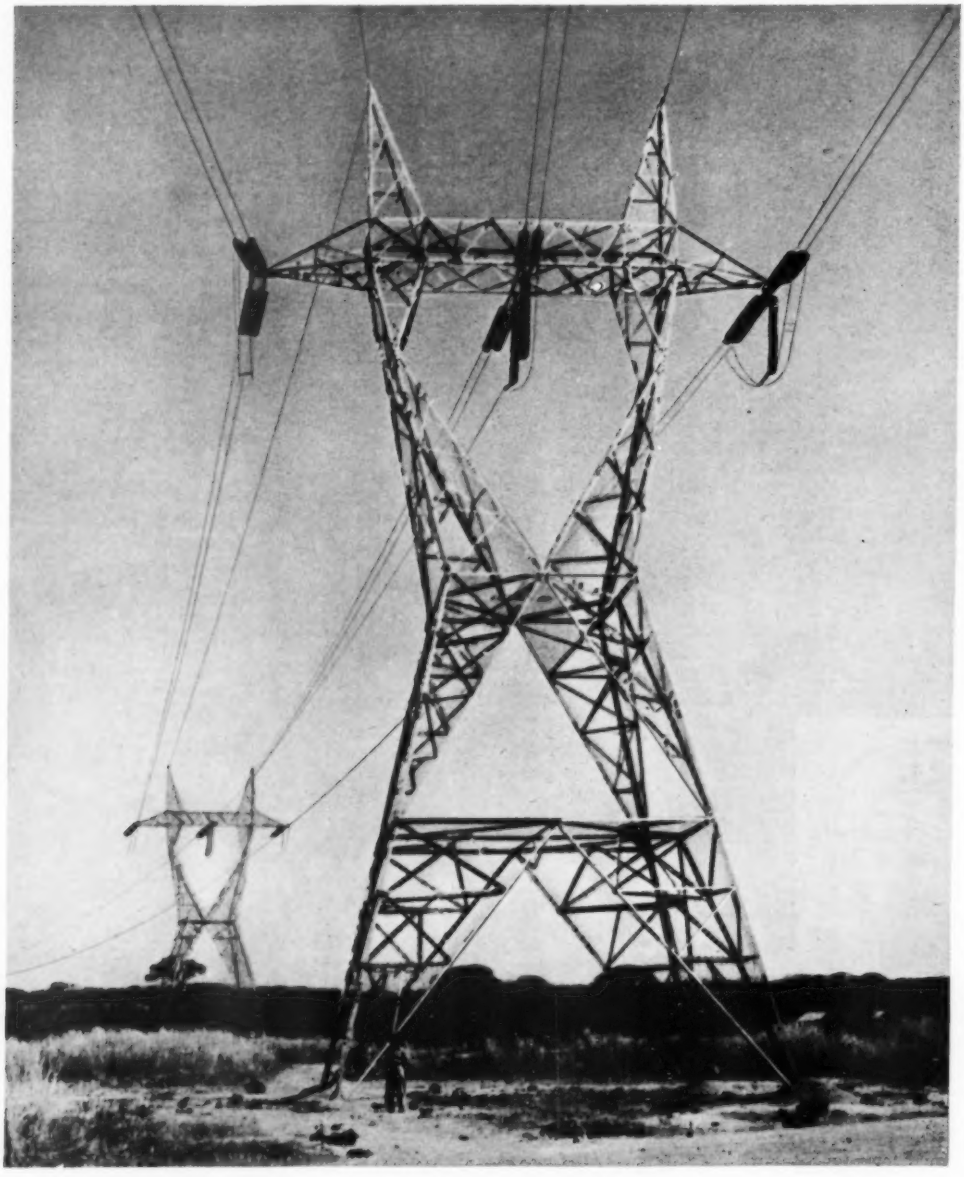

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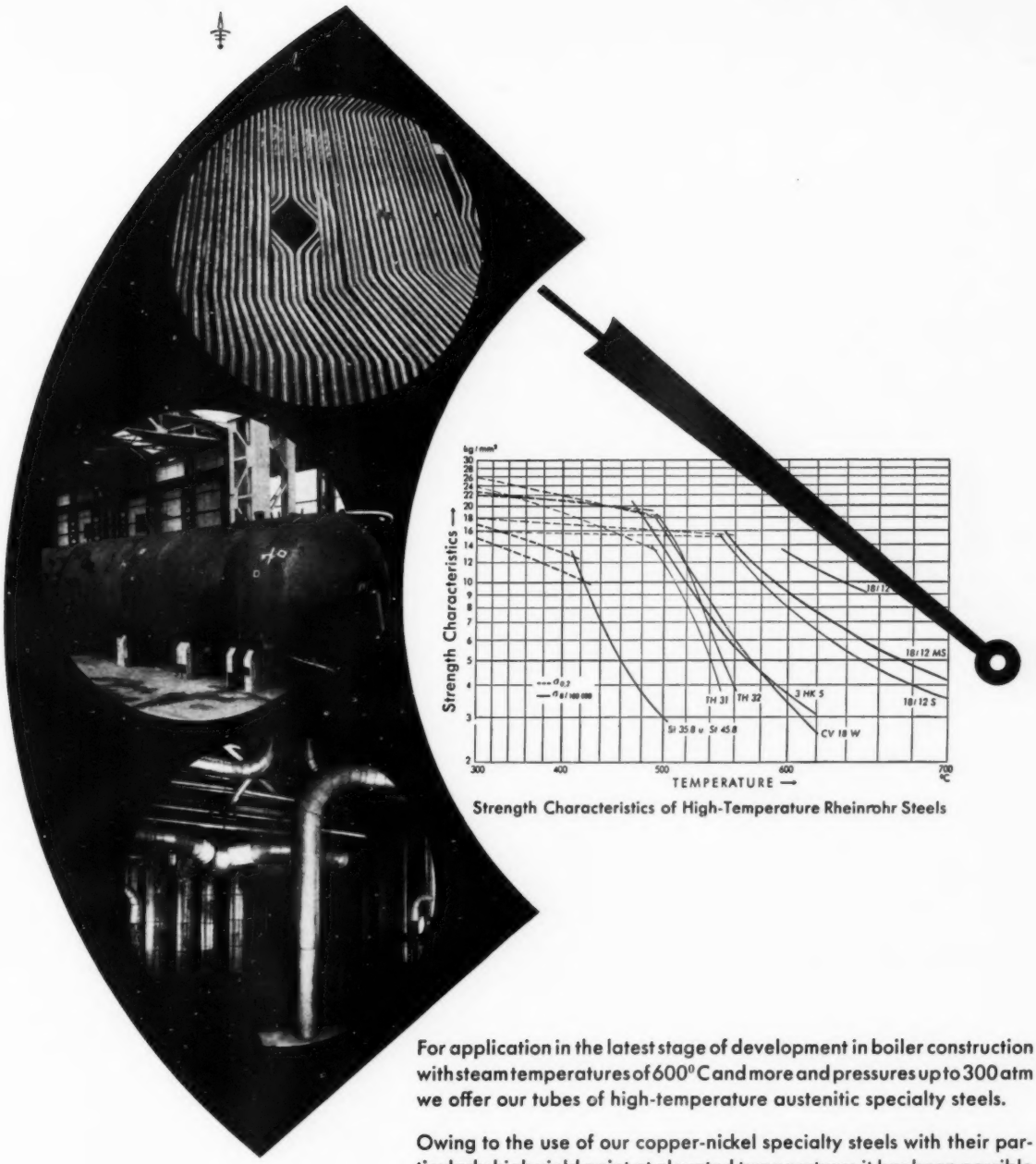

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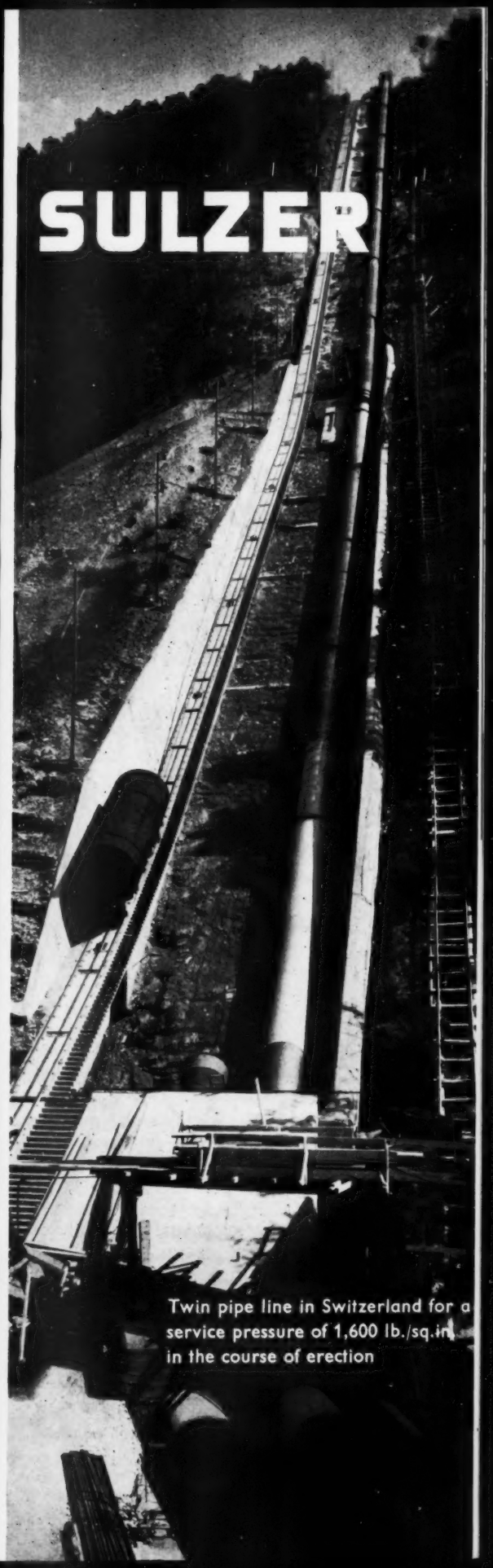
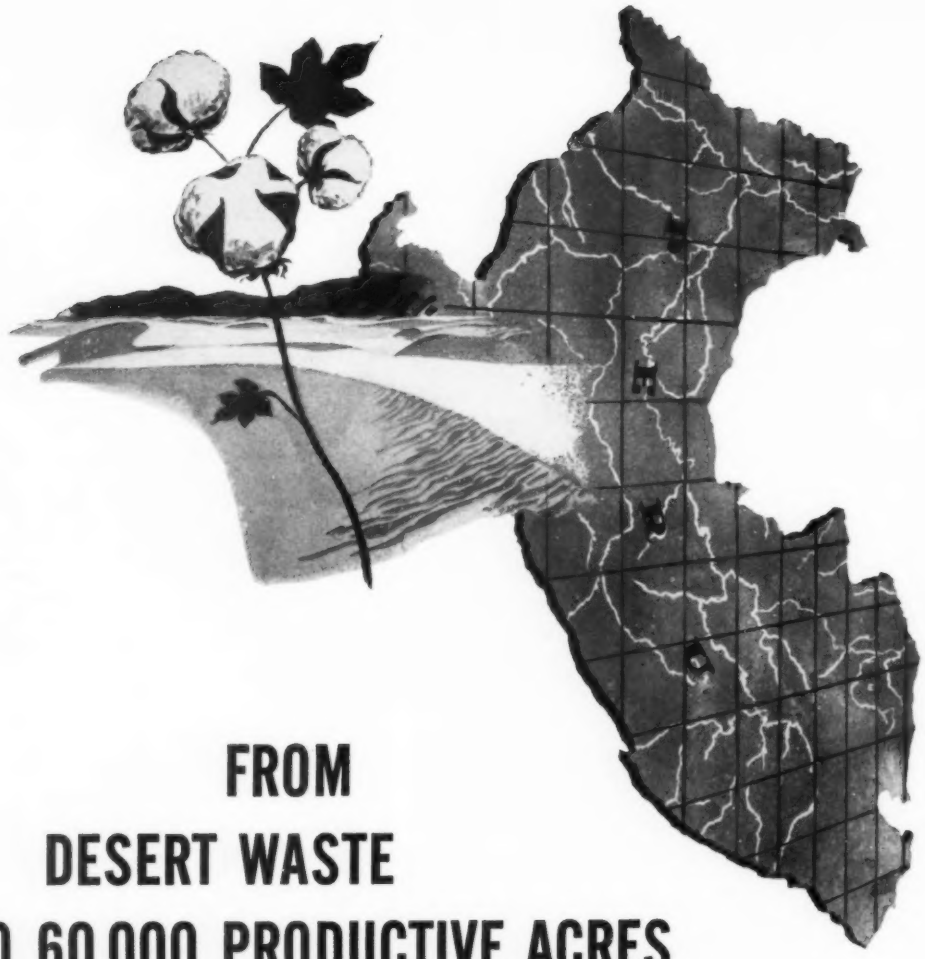


Twin pipe line in Switzerland for a service pressure of 1,600 lb./sq.in. in the course of erection



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When planning power lines, consult

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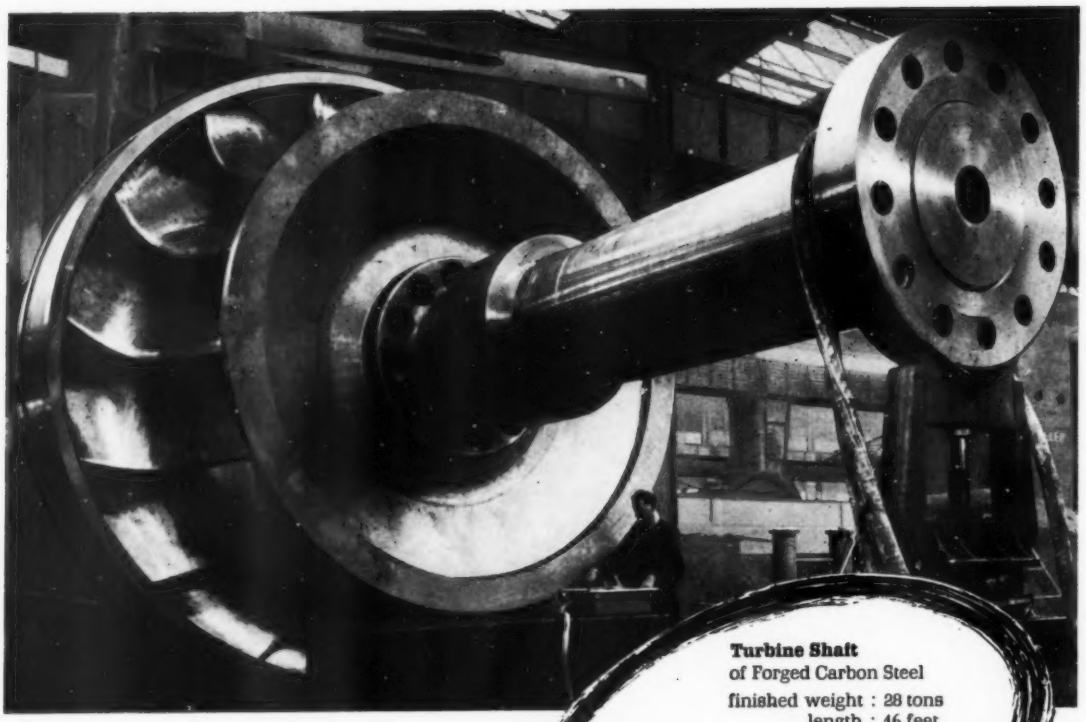

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flange dia. : 59 inches
shaft dia. : 35½ inches

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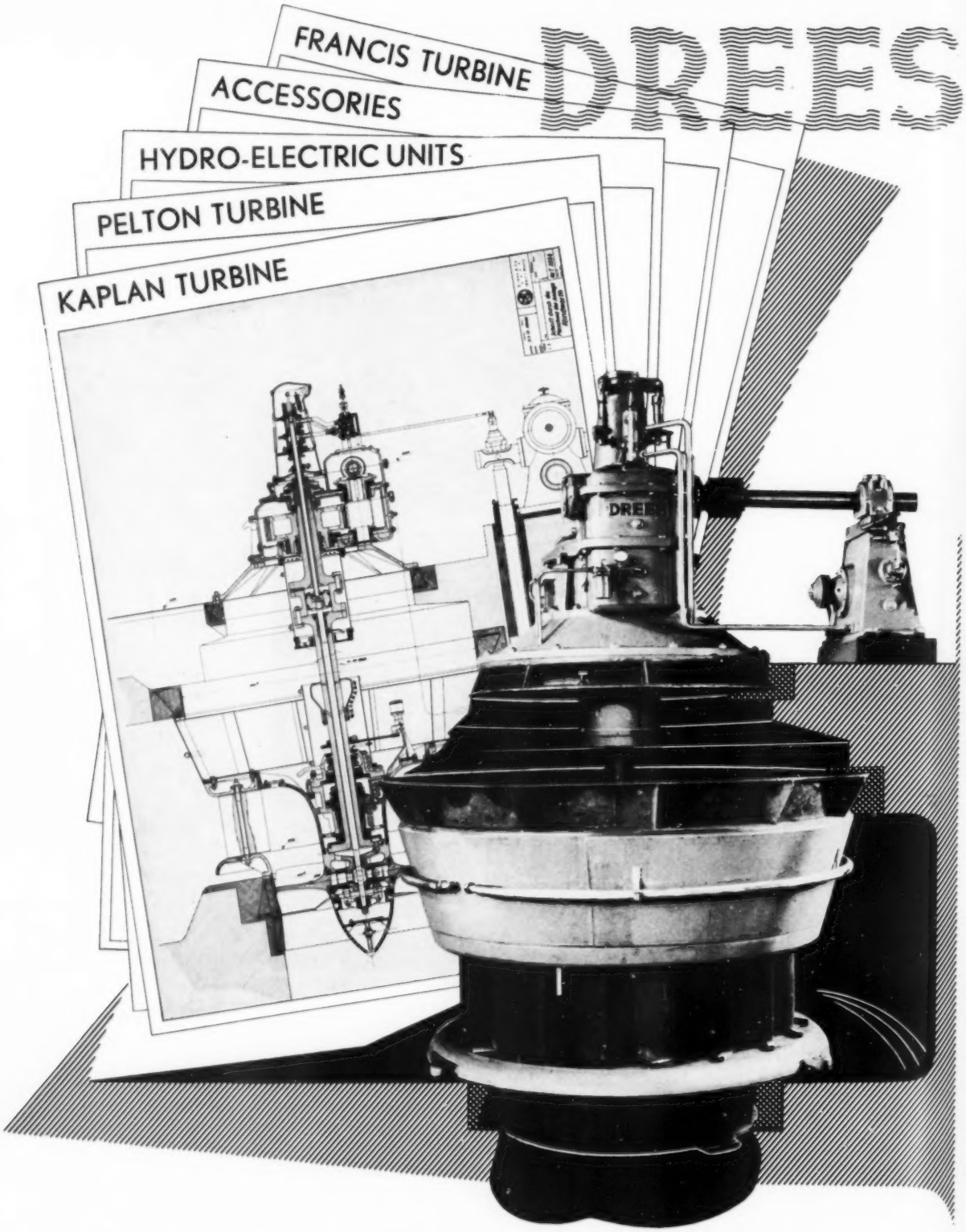

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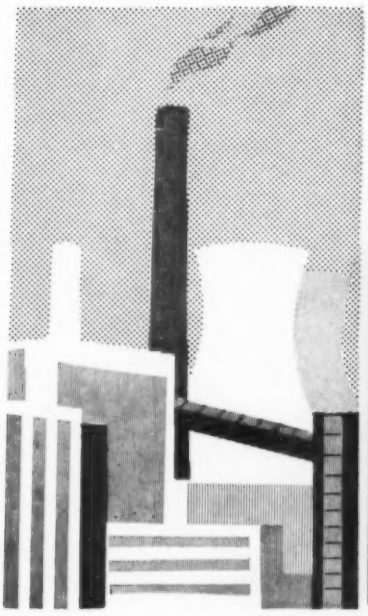
serve the power supplies of Great Britain



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CONSULTING ENGINEERS: SIR WILLIAM HALCROW & PARTNERS

THE MITCHELL CONSTRUCTION COMPANY LTD

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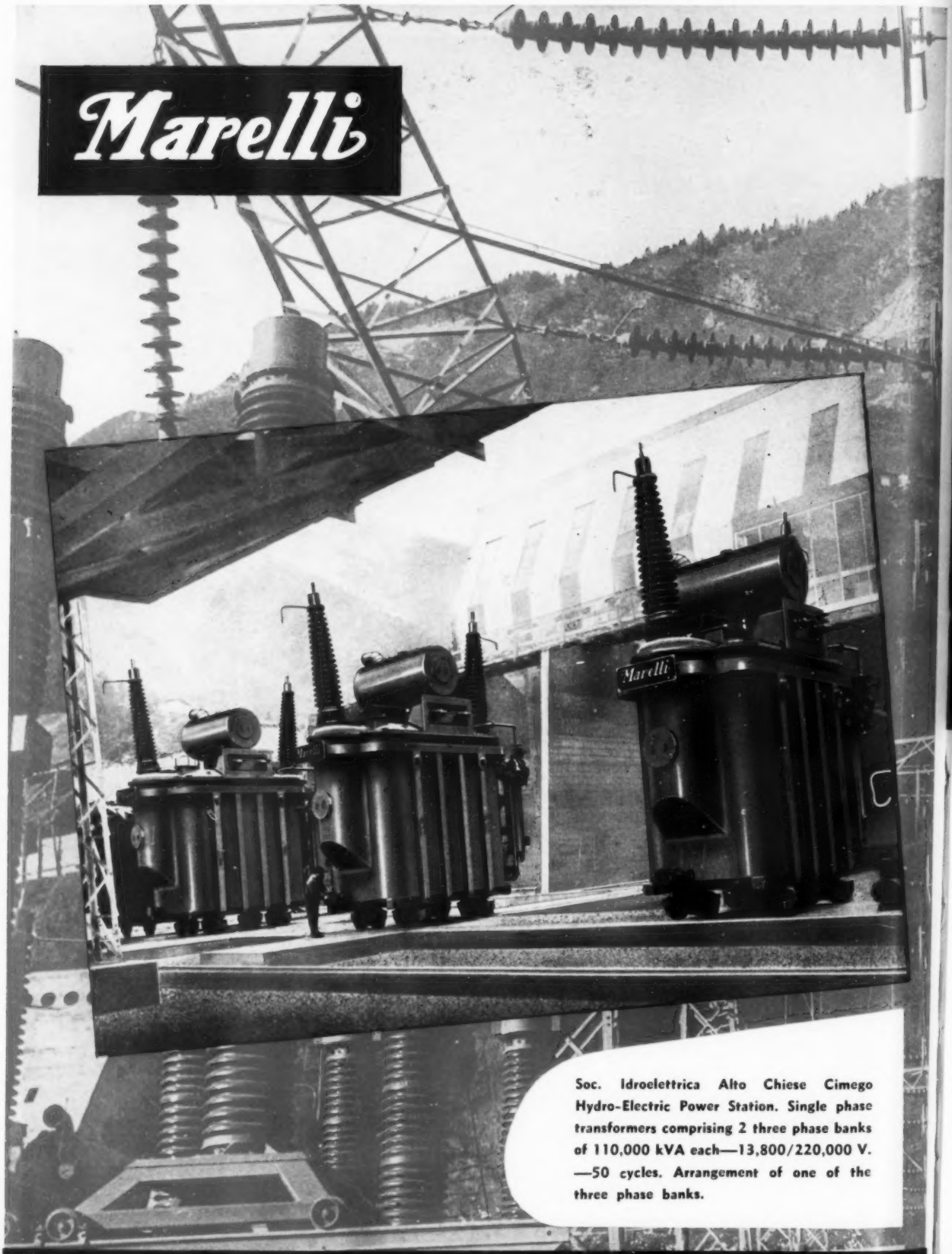

Soc. Idroelettrica Alto Chiese Cimego Hydro-Electric Power Station. Single phase transformers comprising 2 three phase banks of 110,000 kVA each—13,800/220,000 V. —50 cycles. Arrangement of one of the three phase banks.

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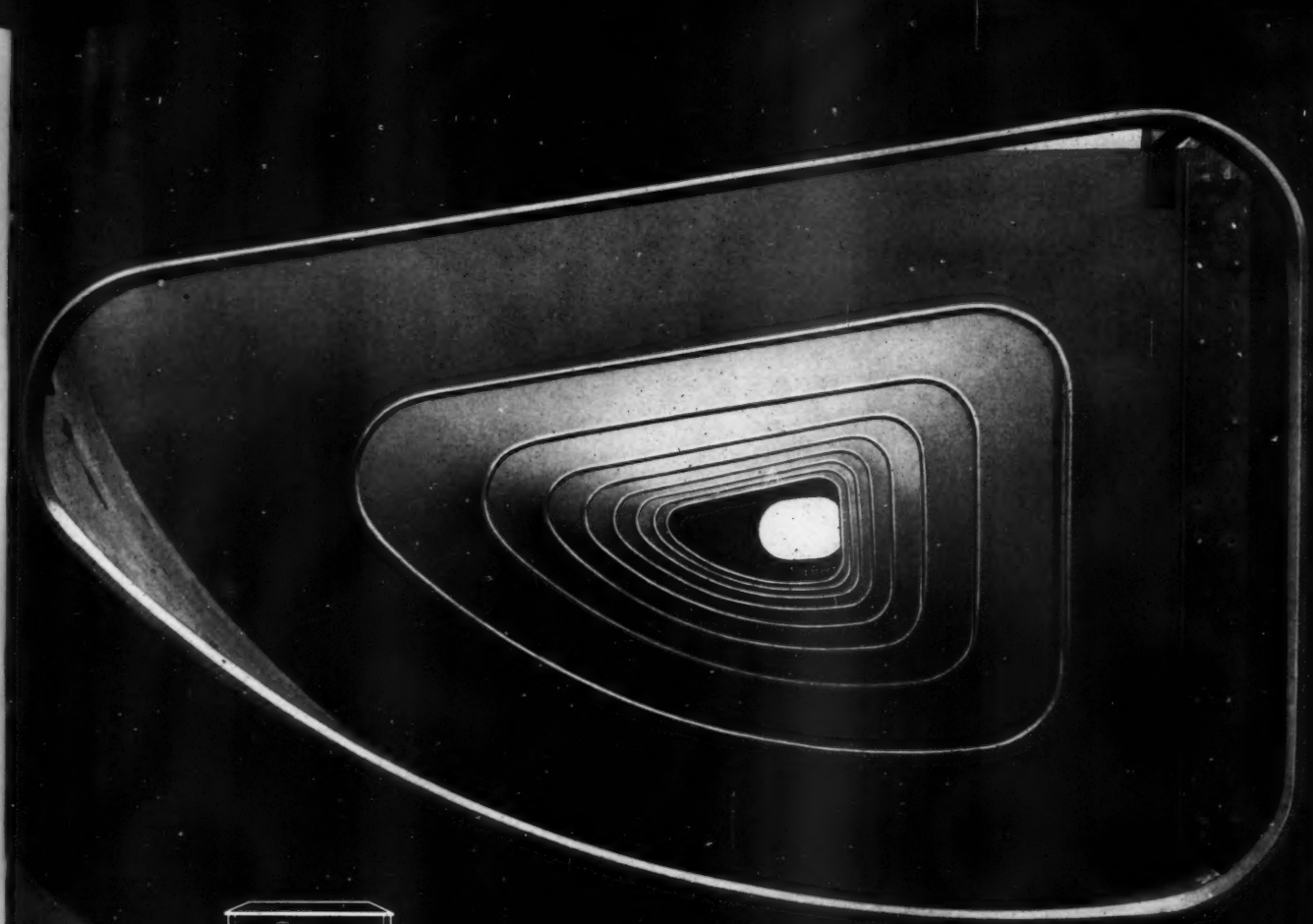

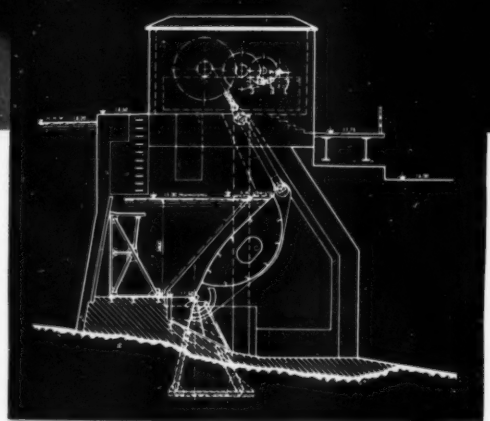

Above: Fishbelly flap, inside view
Centre: Section of a weir with fishbelly flap
Below: Fishbelly flap, 24.5 m. width, 3.8 m. high, assembled in the workshop

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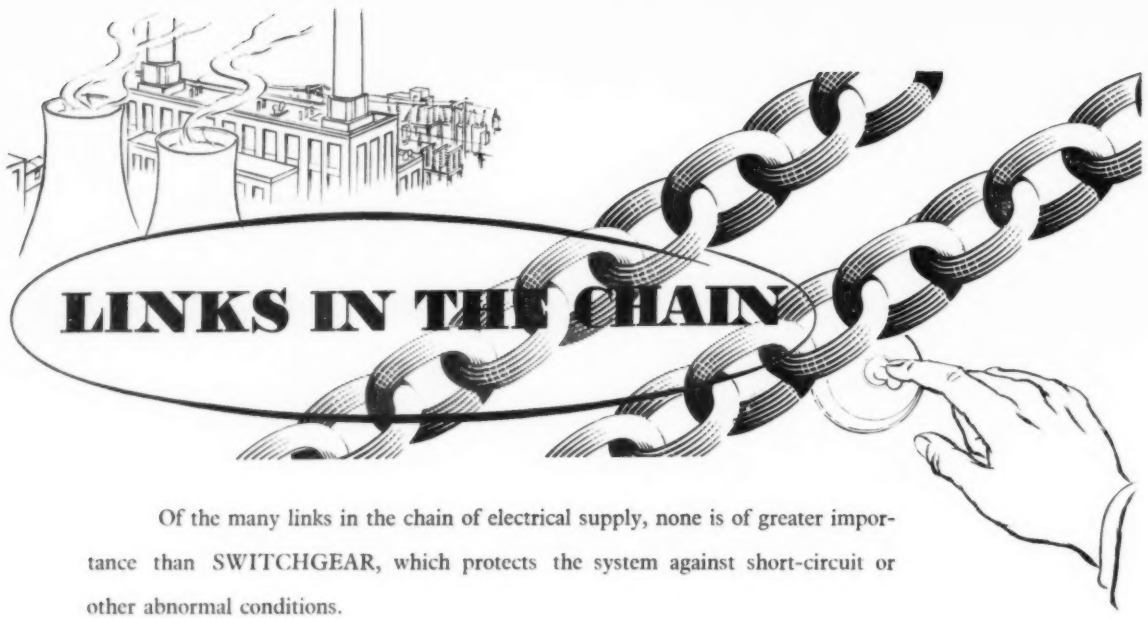

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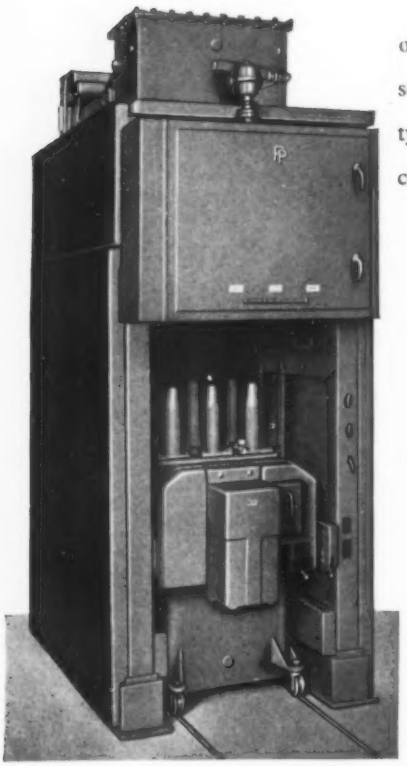
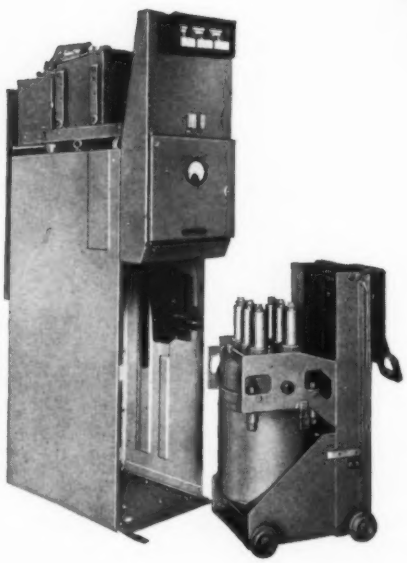
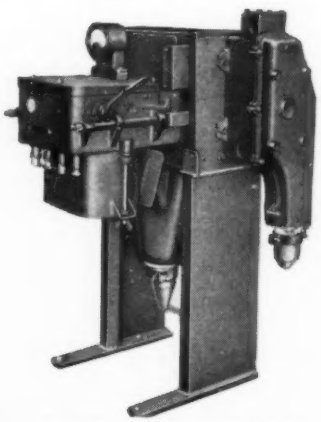
"Ferguson Pailin" have a high reputation for the manufacture of Switchgear of all ratings, from that designed for extra high voltage service within the 'Supergrid', down to medium voltage or industrial type Switchgear which may be found in service in factories and commercial buildings everywhere.



Type VSLP9 Switchgear, rated 1000-MVA breaking capacity at 33-kV.



Type BV Switchgear for 11-kV service up to 250-MVA breaking capacity.



Type K3 pedestal mounted switchgear for service up to 400-A 660-V.

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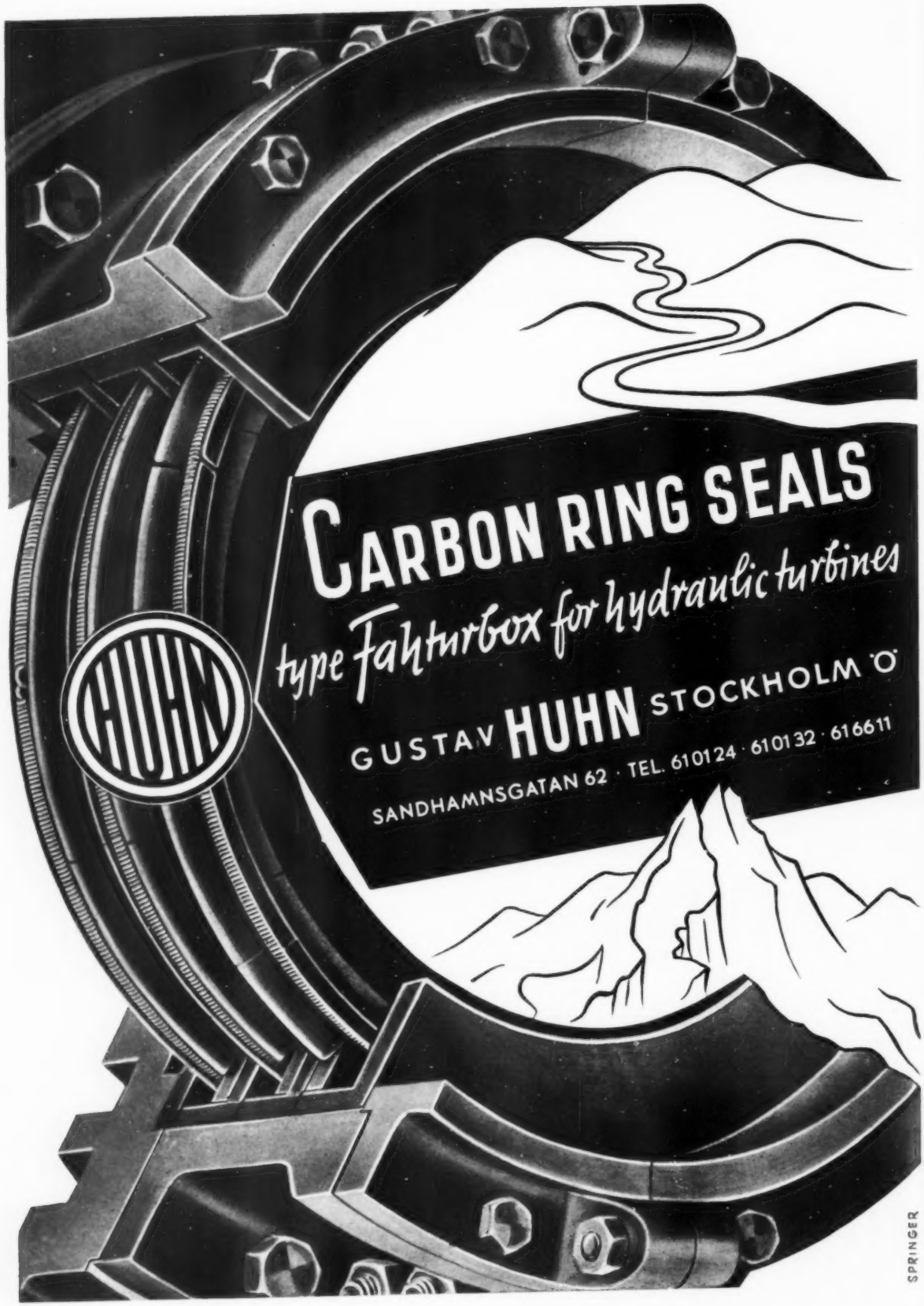
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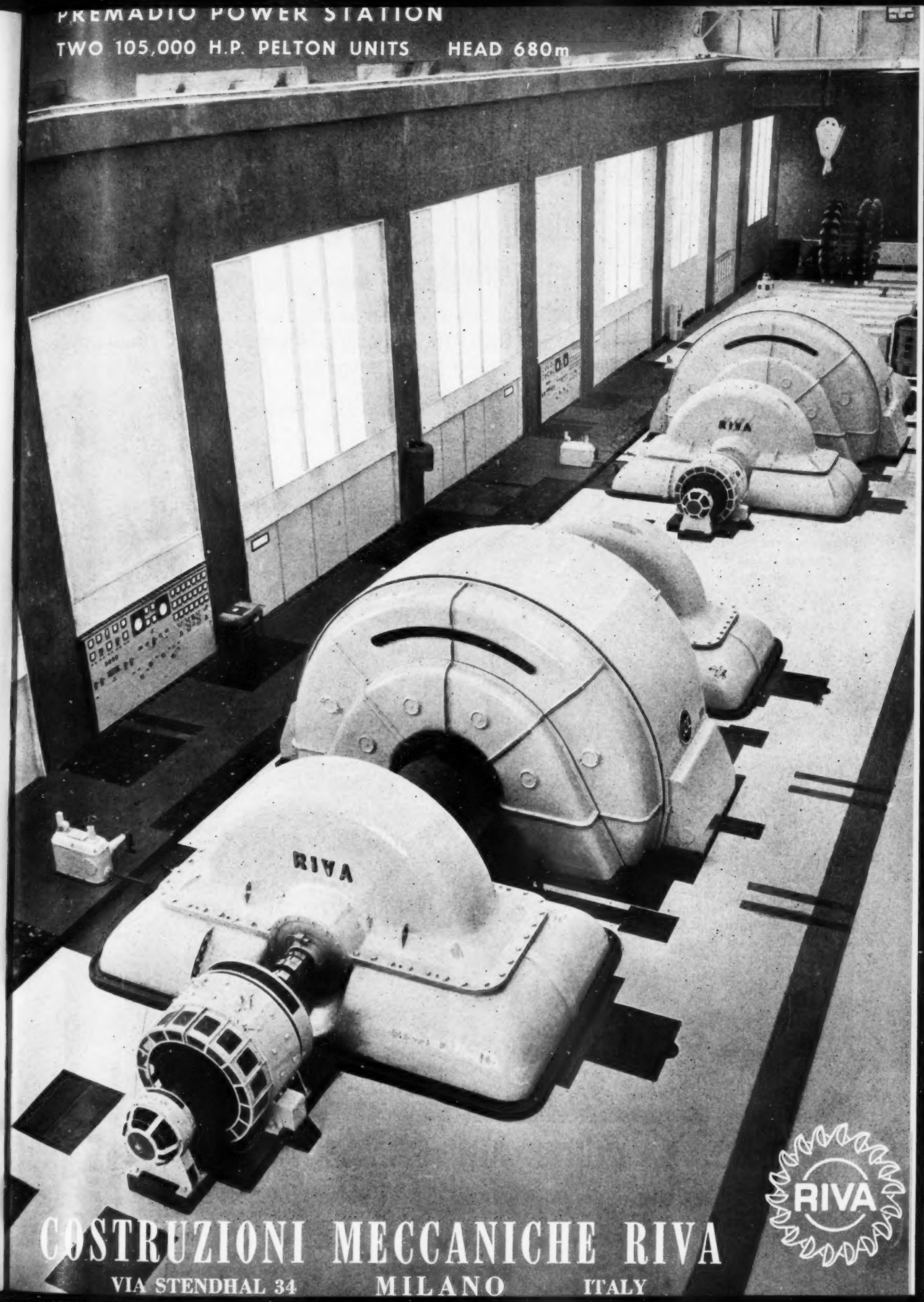
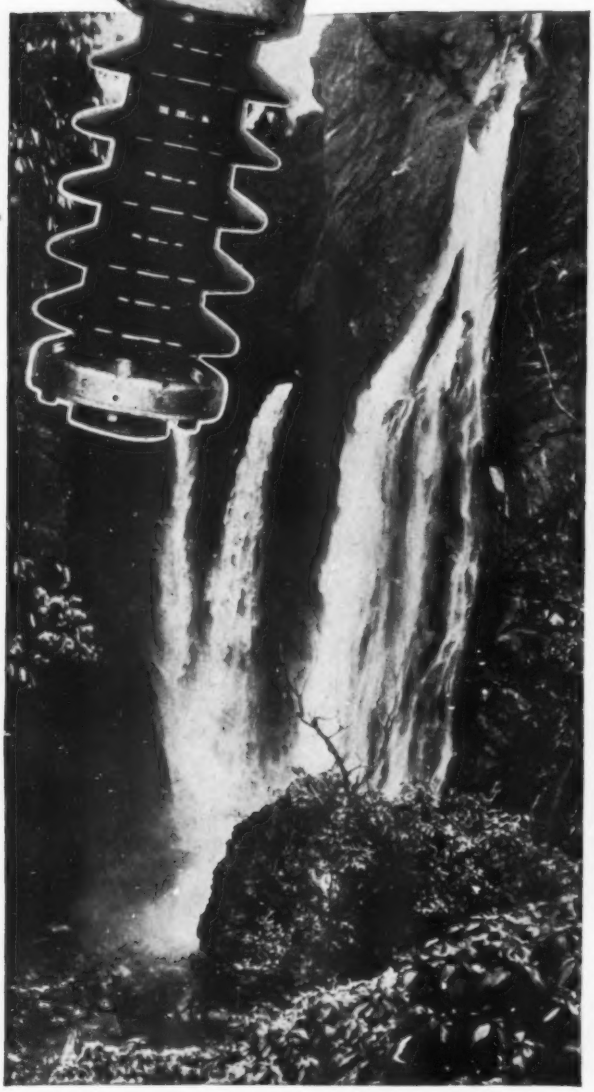


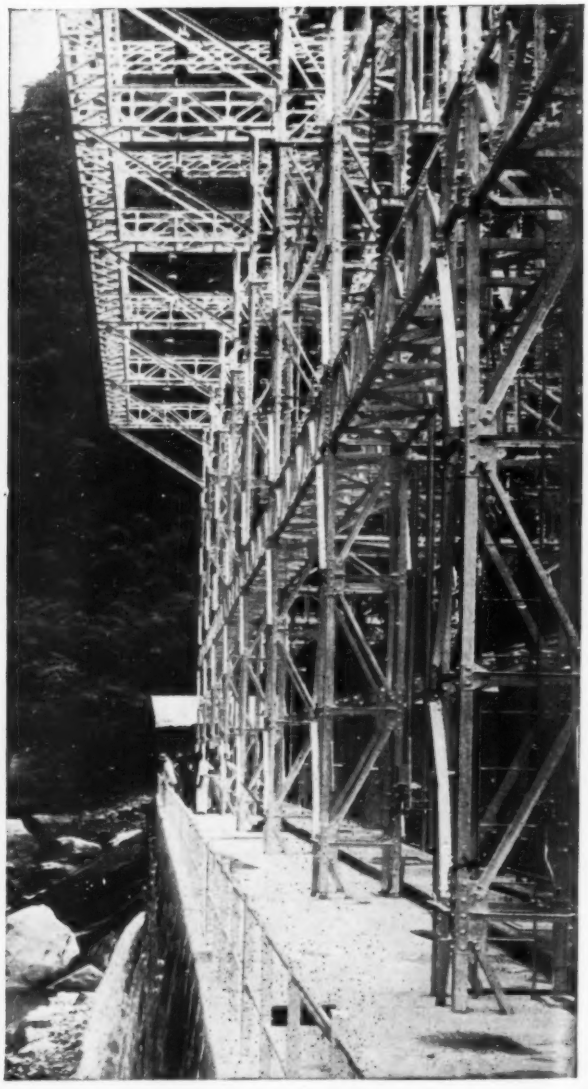
COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY

S.P.P. Post Insulators were used on all the 110kv outdoor switchgear on the Jog Falls Hydro-electric Scheme

The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.





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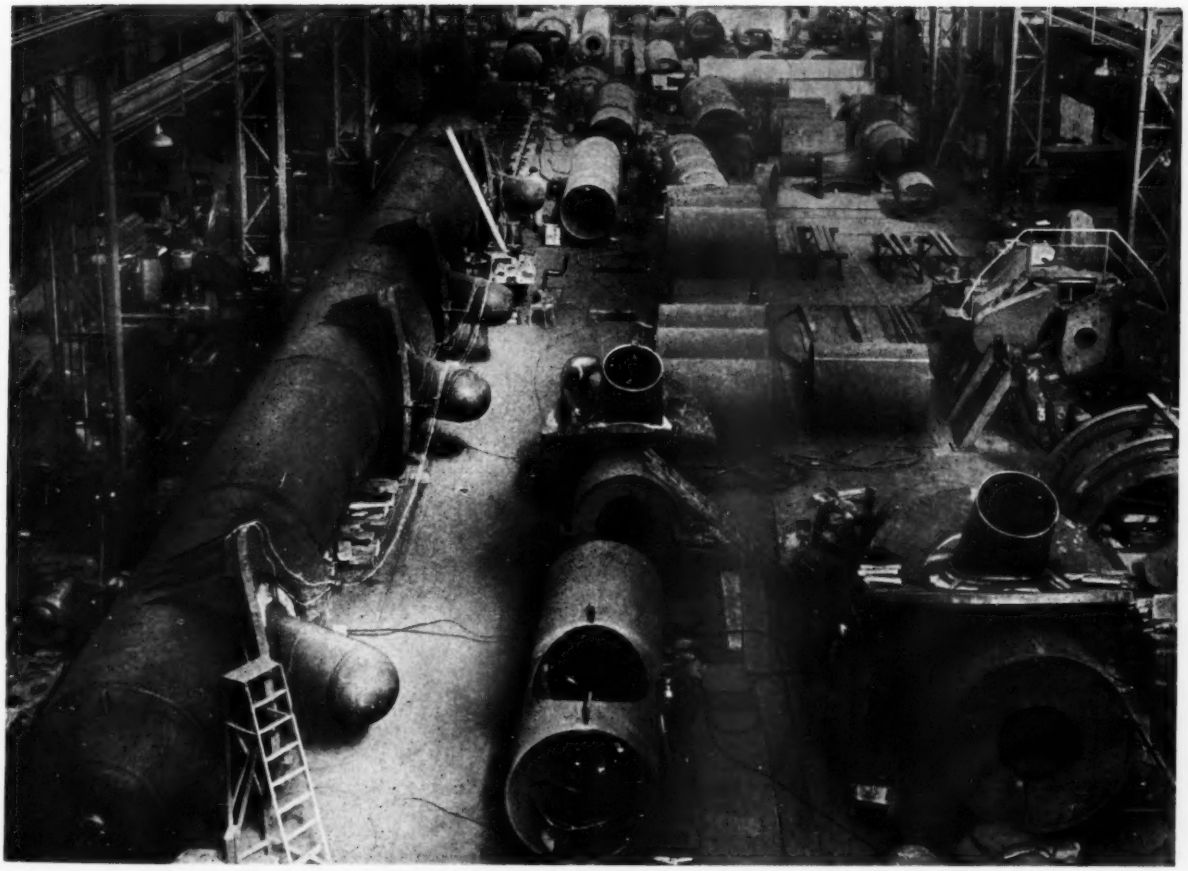
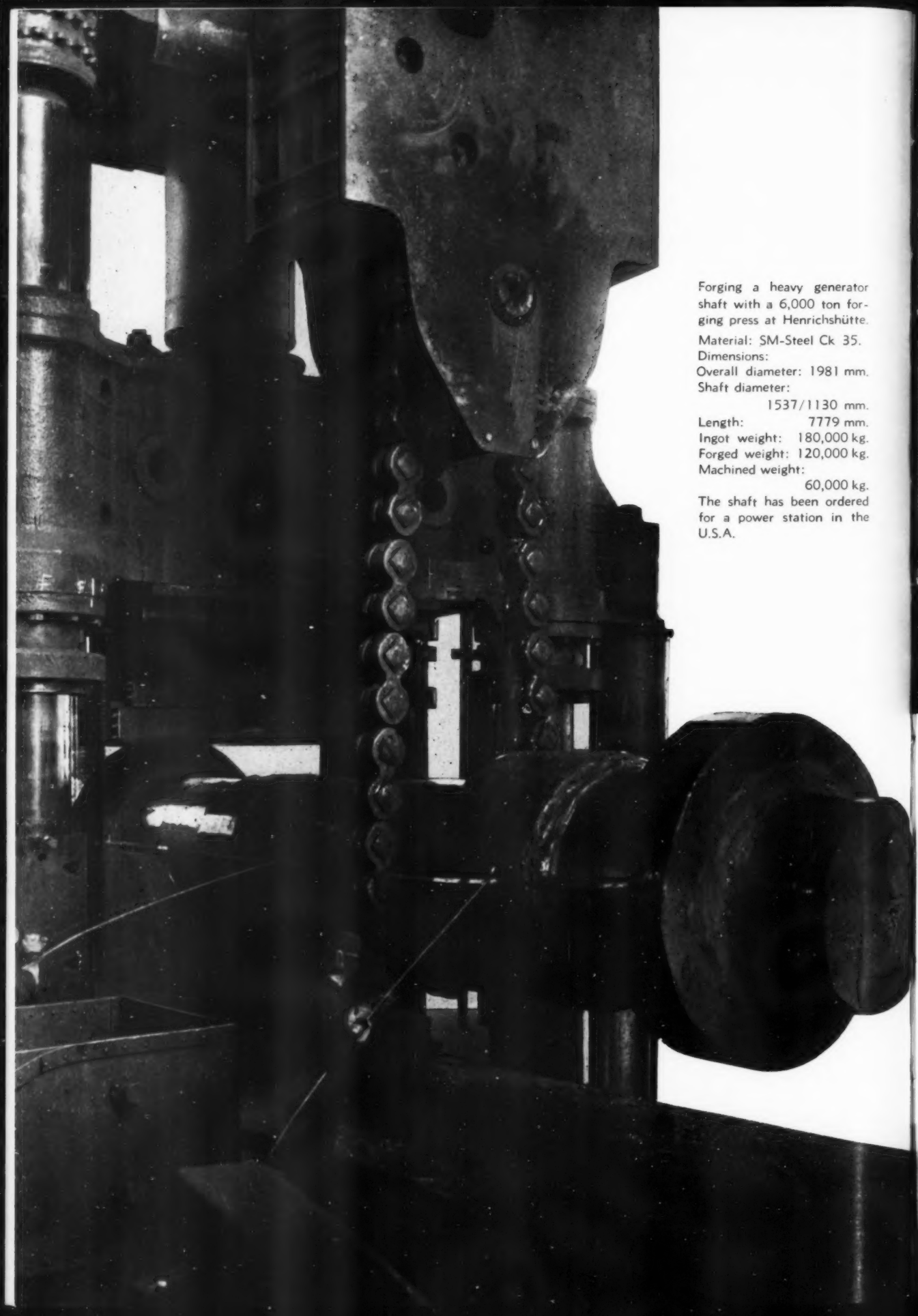


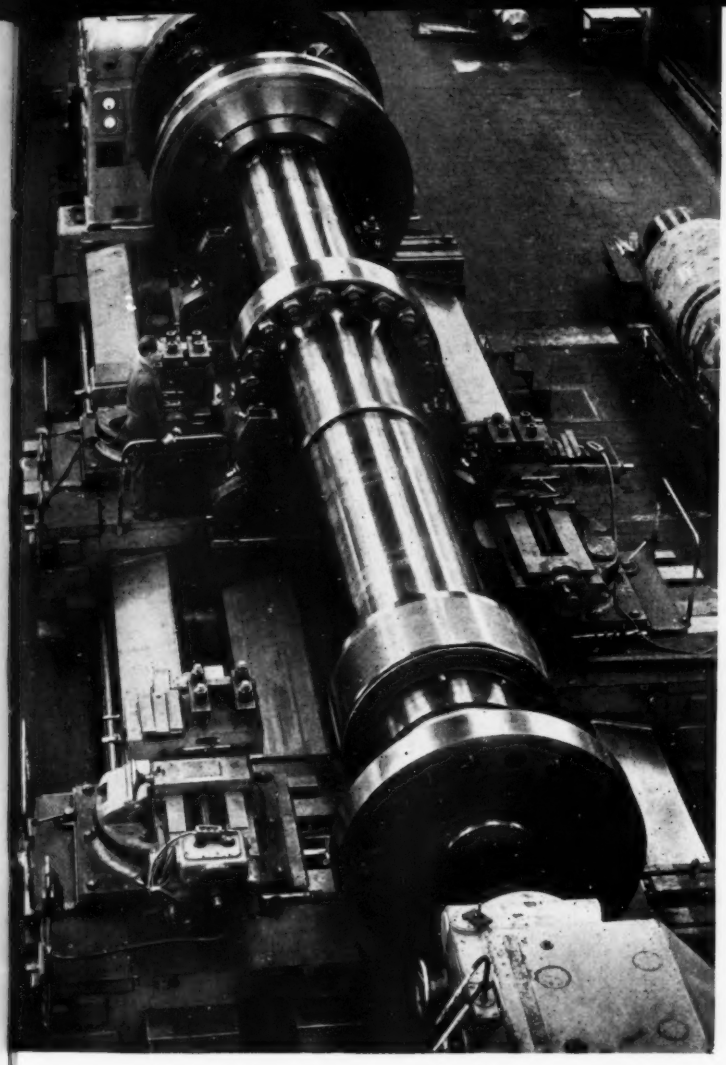
Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

GIOVANOLA **Monthey - Switzerland**



Forging a heavy generator shaft with a 6,000 ton forging press at Henrichshütte.

Material: SM-Steel Ck 35.
Dimensions:
Overall diameter: 1981 mm.
Shaft diameter:
1537/1130 mm.
Length: 7779 mm.
Ingot weight: 180,000 kg.
Forged weight: 120,000 kg.
Machined weight:
60,000 kg.
The shaft has been ordered for a power station in the U.S.A.



Forgings up to
200 tons ingot weight

Heavy forged generator shaft with a shrink-fit thrust collar for PRIEST RAPIDS Power Station in the U.S.A.

Material: SM-Steel Ck 35
Overall diameter: 2851 mm.
Length: 6991 + 4394 = 11,385 mm.
Total weight: 95,700 kg.

Sole Agents in the U.K.:
DRUMMOND ASQUITH (SALES) LIMITED
Halifax House, Strand, LONDON, W.C.2. Phone: TRAfalgar 7224
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Supply the heaviest components for **INDUSTRIAL PLANT**

RUHRSTAHL AG

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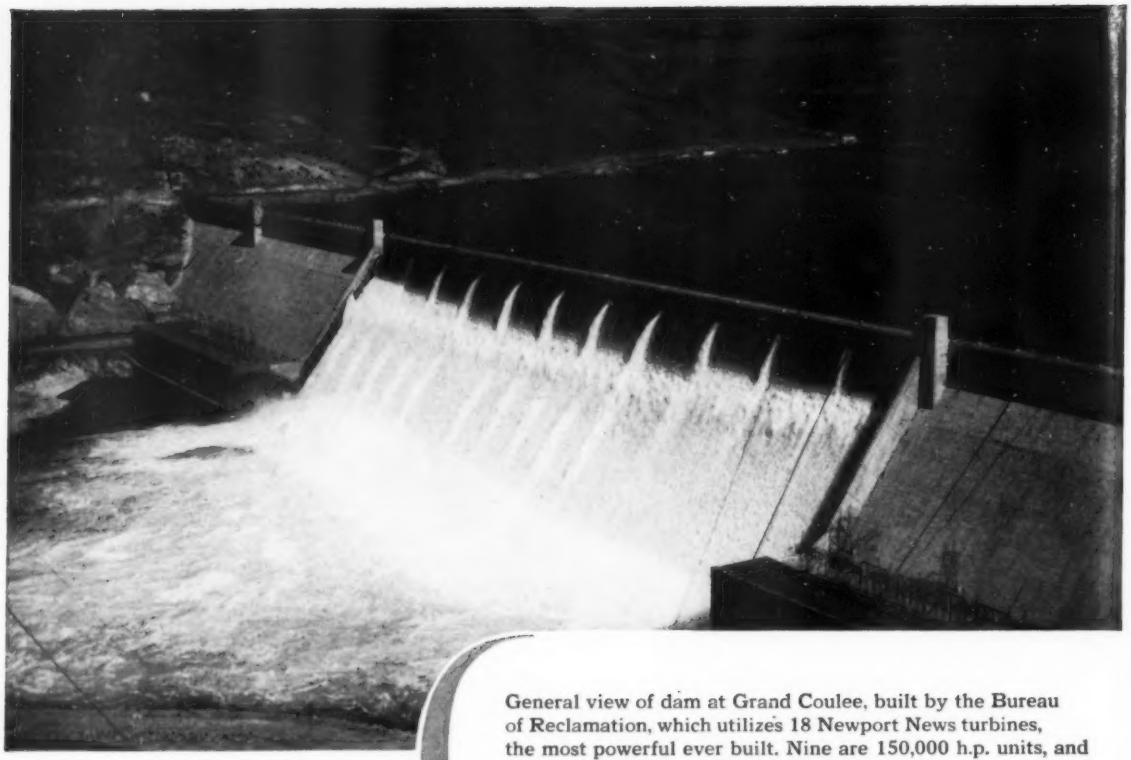


General view of dam at Grand Coulee, built by the Bureau of Reclamation, which utilizes 18 Newport News turbines, the most powerful ever built. Nine are 150,000 h.p. units, and the other nine are rated at 165,000 h.p. each.

Specialists ... in building Water Power Equipment

Typical Users of Newport News Equipment

PLANT	LOCATION
Boone	Tennessee
Buchanan	Texas
Caonillas	Puerto Rico
Chief Joseph	Washington
Clark Hill	South Carolina
Deer Lake	Newfoundland
Folsom	California
Fort Patrick Henry	Tennessee
Hiwassee	Tennessee
Hoover	Nevada
J. H. Kerr	Virginia
Jim Woodruff	Florida
Lower Salmon	Idaho
Norris	Tennessee
Rock Creek	California
Santee-Cooper	South Carolina
C. J. Strike	Idaho
Whitney	Texas
Wilson	Alabama

Turbines designed and built for the world's largest development at Grand Coulee... and for other hydroelectric installations in America and various parts of the world... bespeak the skill and facilities offered by Newport News.

This trained organization has filled hydroelectric turbine contracts with an aggregate rated output of 7,000,000 horsepower.

Other equipment designed and built by Newport News includes penstocks, pressure regulators, valves, pumps, gates and rack rakes. Upon request, a copy of our illustrated booklet entitled "WATER POWER EQUIPMENT" will be sent to you.

Newport News
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

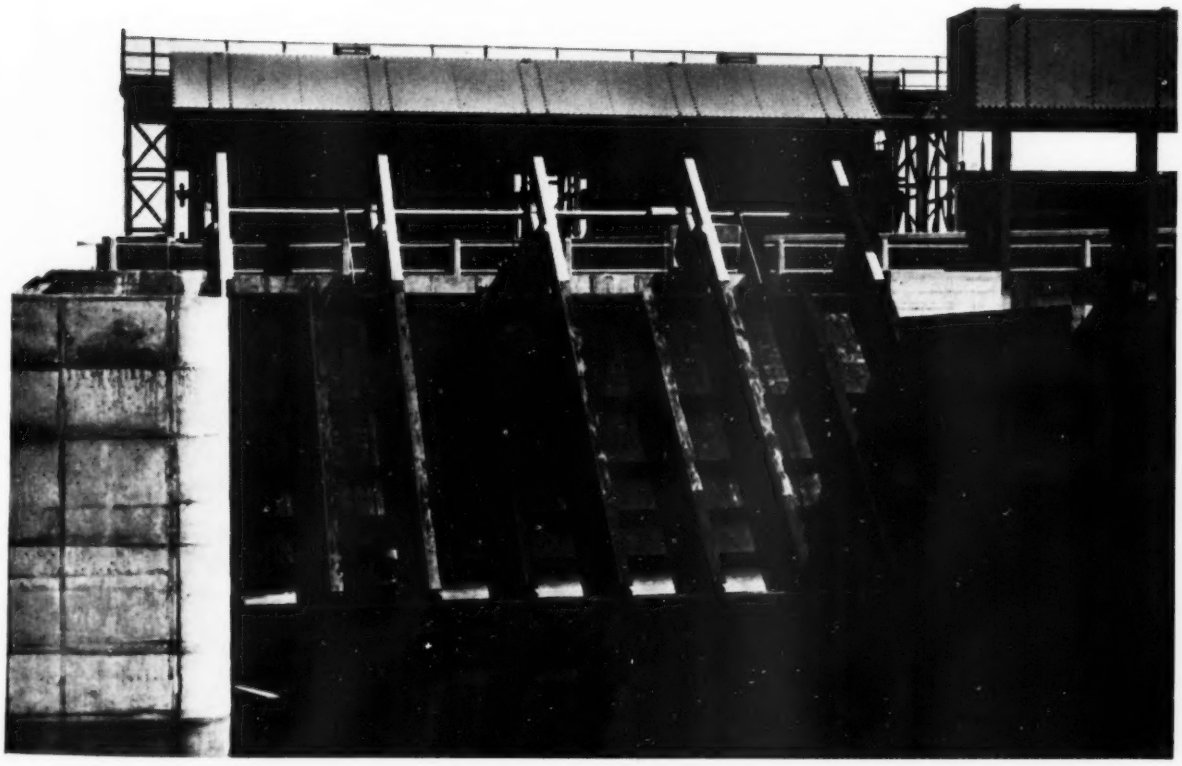
RAPIER

WATER CONTROL GATES

for
RIVER CONTROL
WATER SUPPLY
POWER PLANTS
IRRIGATION
LOCKS AND DOCKS

RapieR Sluice Gates are at both ends of the Spalding Flood Relief Channel, River Welland. Illustration shows one of the three tidal flap gates at the Marsh Road end. Each gate is 30 feet span by 18 feet deep to pass flood waters and prevent tidal waters entering the channel.

Three RapieR wheel gates, each 30 feet span by 19 feet deep are at the Cowbit Road end of the channel.



RANSOMES & RAPIER LTD. IPSWICH.

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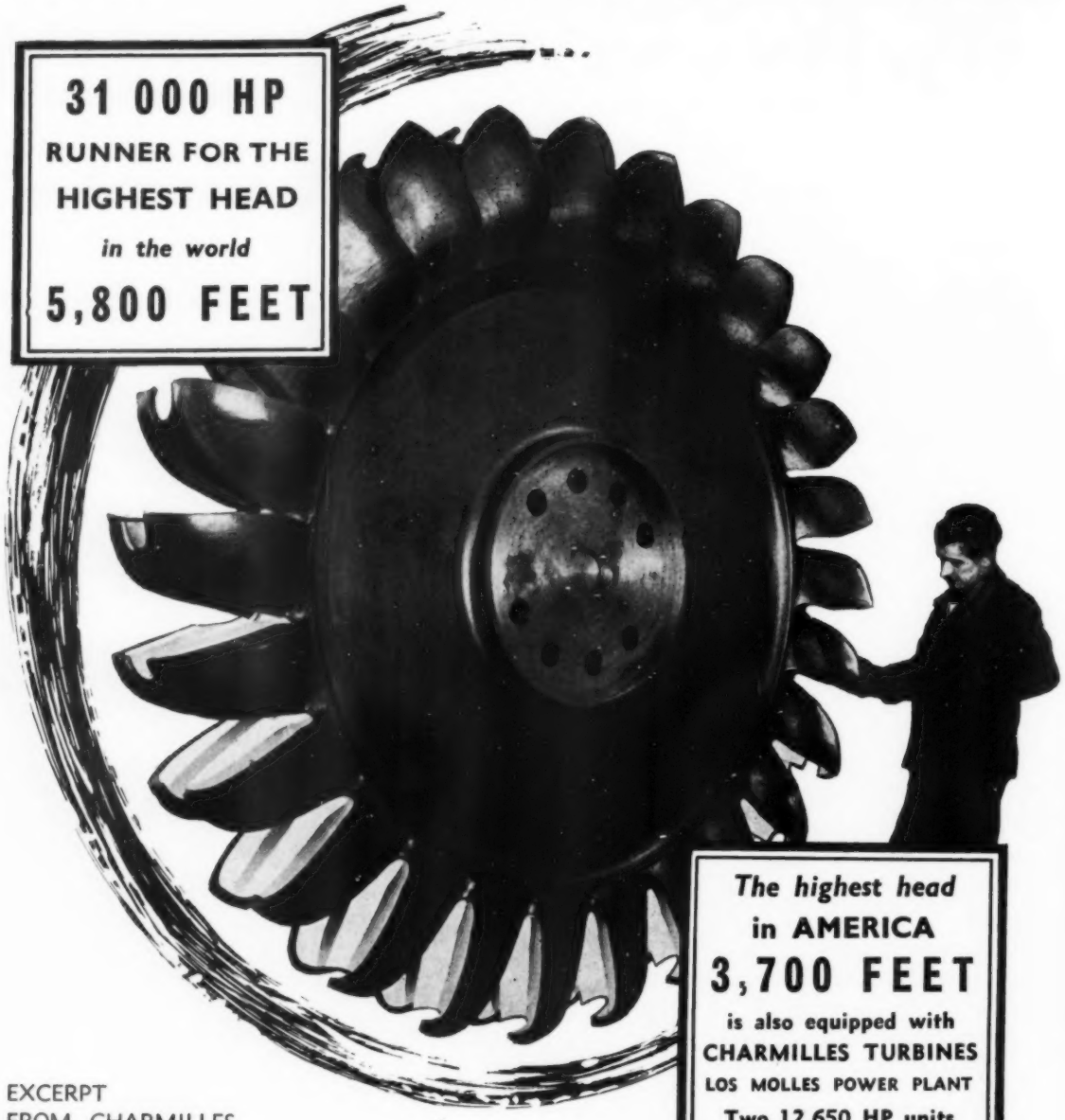
CHARMILLES ENGINEERING WORKS LTD. - GENEVA

31 000 HP
RUNNER FOR THE HIGHEST HEAD
in the world
5,800 FEET



The highest head
in AMERICA
3,700 FEET
is also equipped with CHARMILLES TURBINES
LOS MOLLES POWER PLANT
Two 12,650 HP units

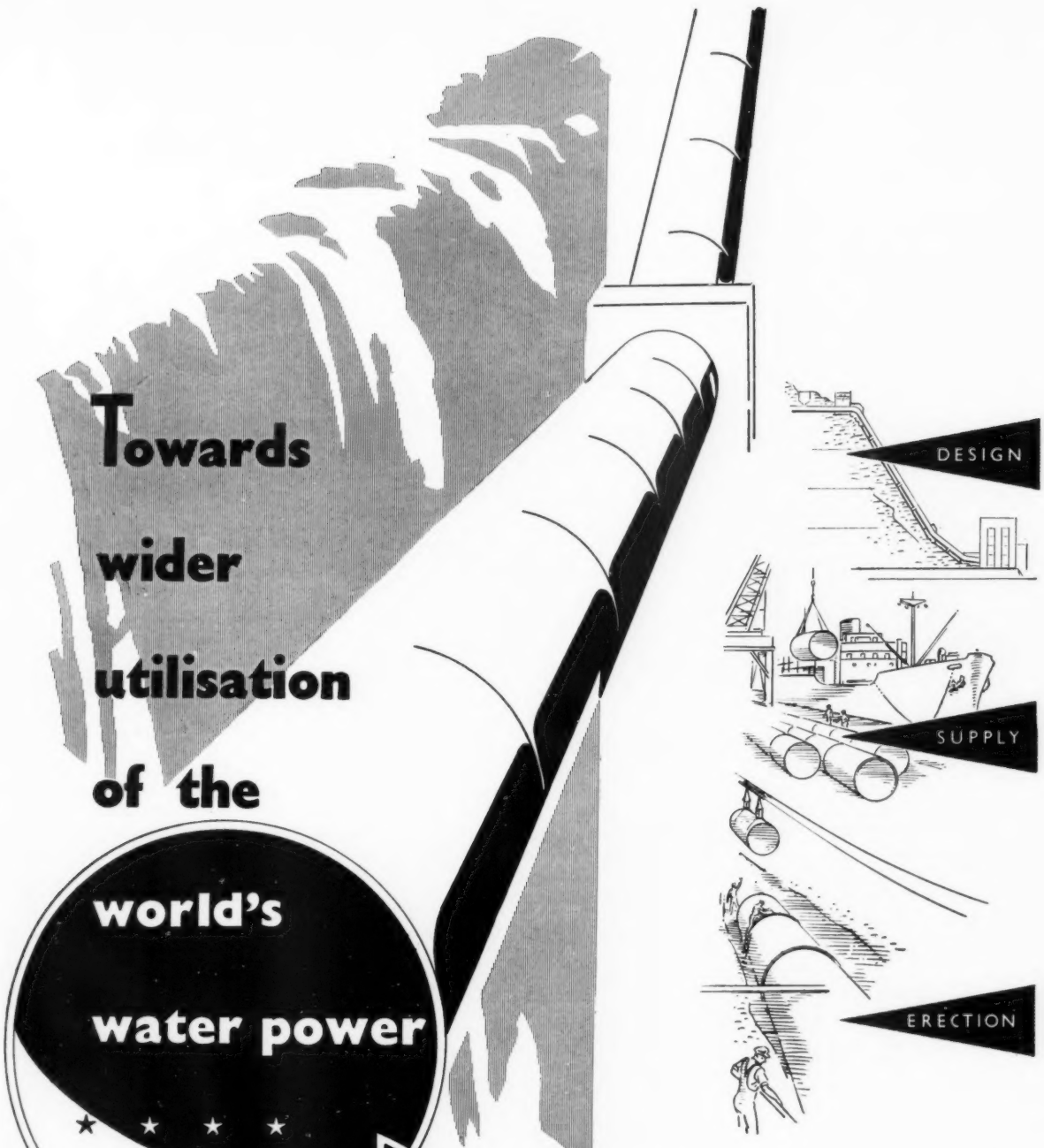
EXCERPT
FROM CHARMILLES
REFERENCE LIST

THE SIXTEEN HIGHEST HEAD TURBINES IN THE WORLD

Installation	Number of units	Net head feet	Unit output HP
Reisseck (Austria)	3	5,800	31,000
Dixence (Switzerland)	5	5,700	50,000
*Fully (Switzerland)	4	5,400	3,000
Miéville (Switzerland)	3	4,730	47,500
Portillon (France)	1	4,280	53,500

*manufactured in the time of Pic-Pic

No other turbine in the world operates with a head equal to or higher than any of the above



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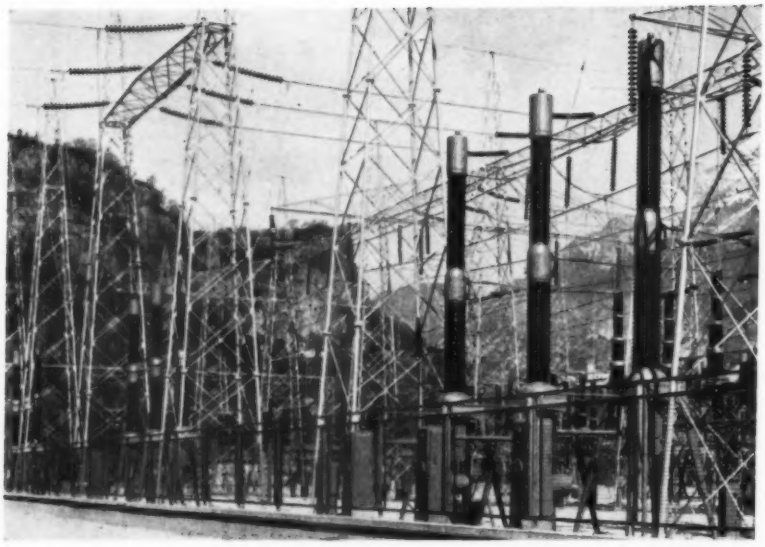
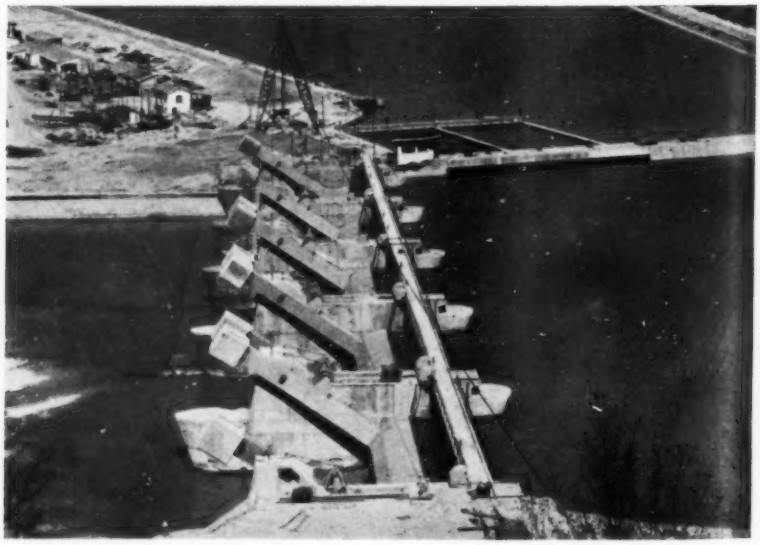
TELEPHONE: 38 05 86 · CABLES: FERRUMSTEEL, OSLO

OFFICINE ELETTRO MECCANICHE GALILEO
DI BATTAGLIA TERME S.p.A.



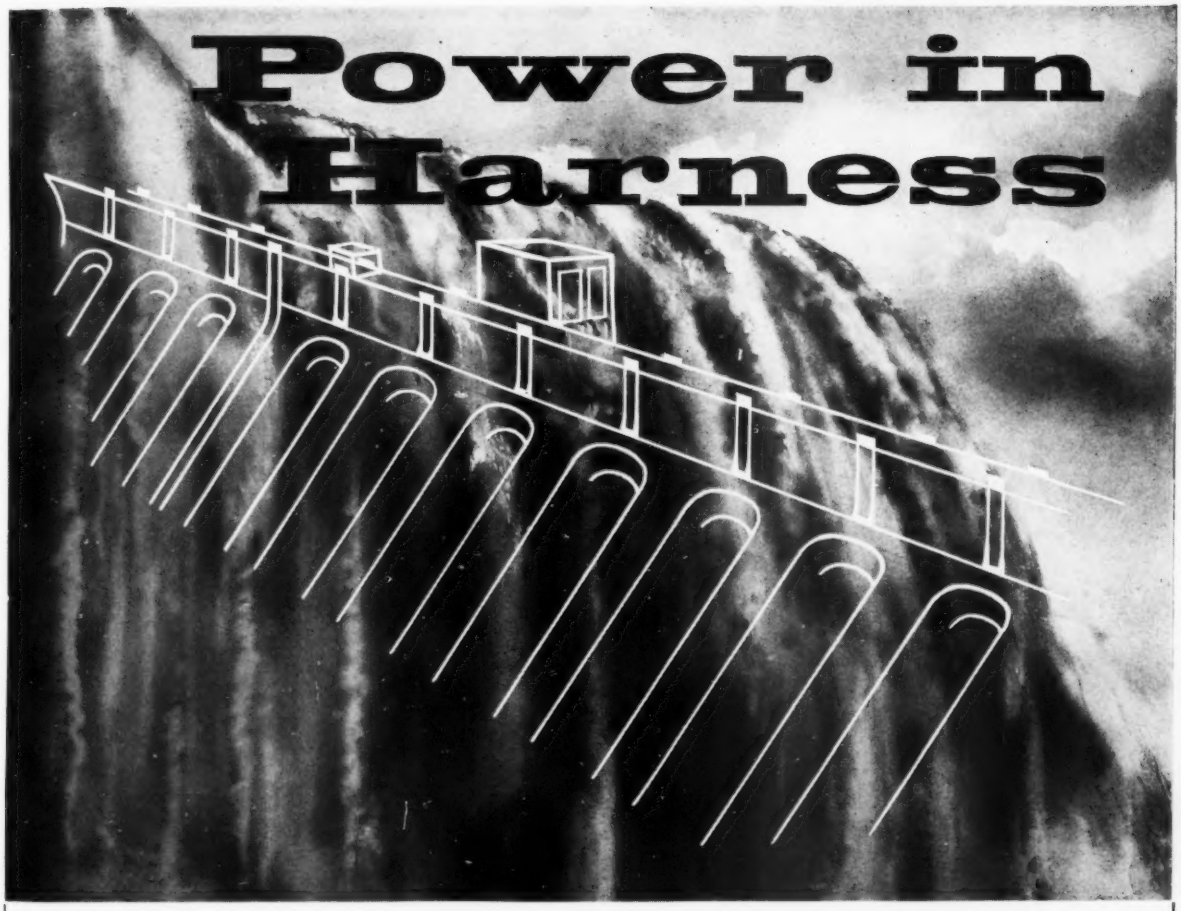
circuit breakers, isolating switches and measuring transformers for 220 kV. Somplago Power station

Officine Elettromeccaniche Galileo build electrical equipment for medium, high and ultra-high voltage, travelling cranes, gates of any type, racks, rack rakes and any other metallic frame for hydro-electric plants



barrage on the Volturno river five automatic sector gates 25 mt. wide; 375 mt. high

For offers and details, please enquire to: Officine Elettromeccaniche Galileo, Servizio Commercio Estero, via Larga, 26, Milano (Italy) — Phone: 877895. Grams: Elettroga, Milano



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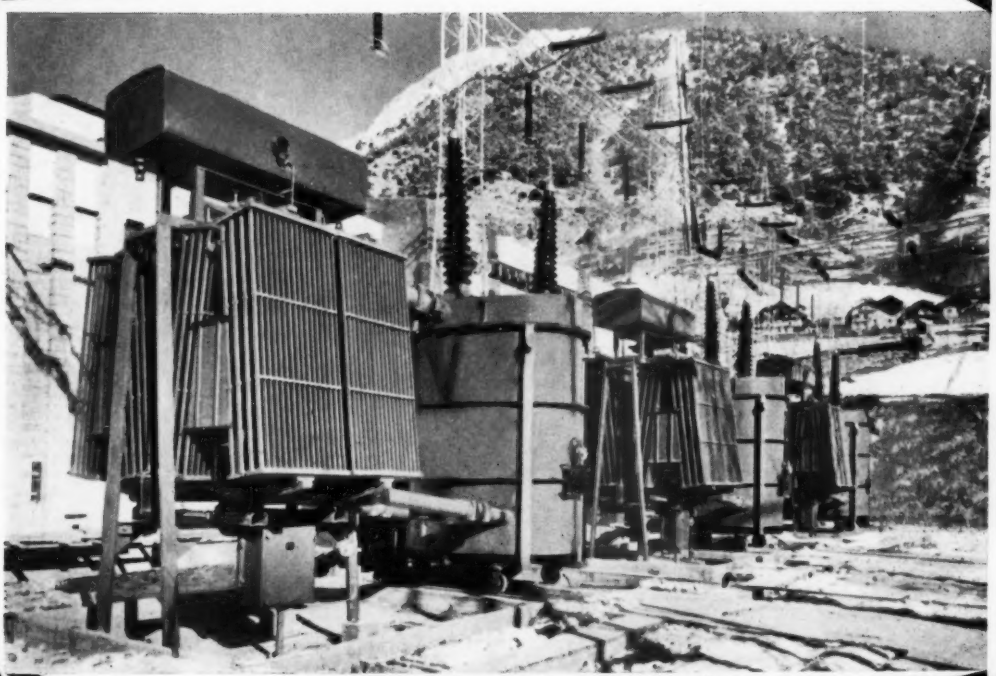

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Complete Equipment
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Turbines of the Kaplan, Francis and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc.
The world-known ŠKODA and ČKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.
TECHNOEXPORT
Foreign Trade Corporation for Export of complete Industrial Plants
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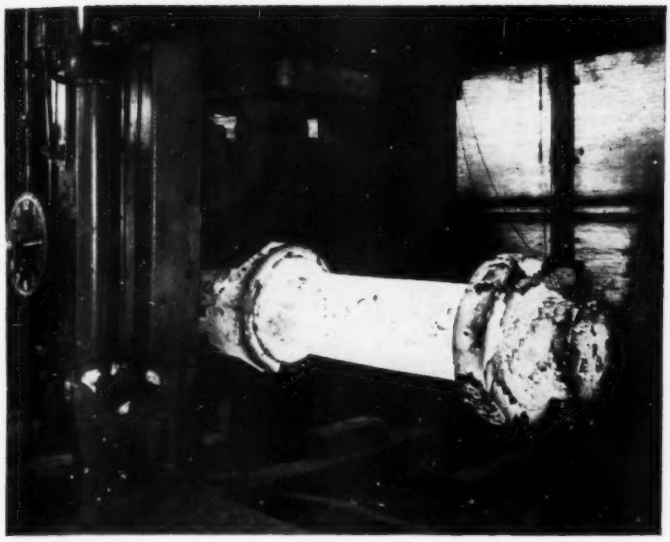
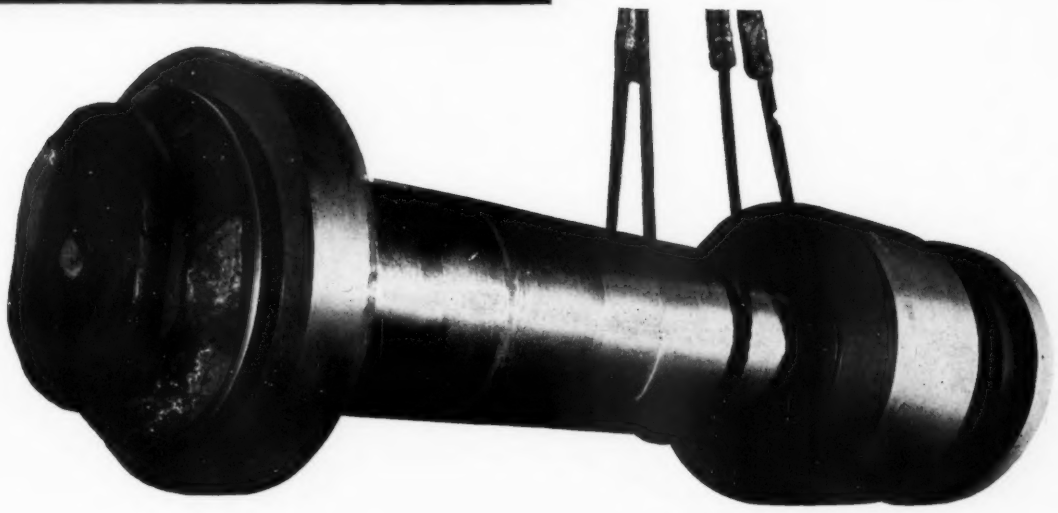
CZECHOSLOVAKIA



For many years ESC has been a leading supplier of steel forgings to many vital industries. Forgings in weights up to 175 tons are manufactured in our high quality carbon and alloy steels—single piece engineering units produced from ingots weighing up to 275 tons—and



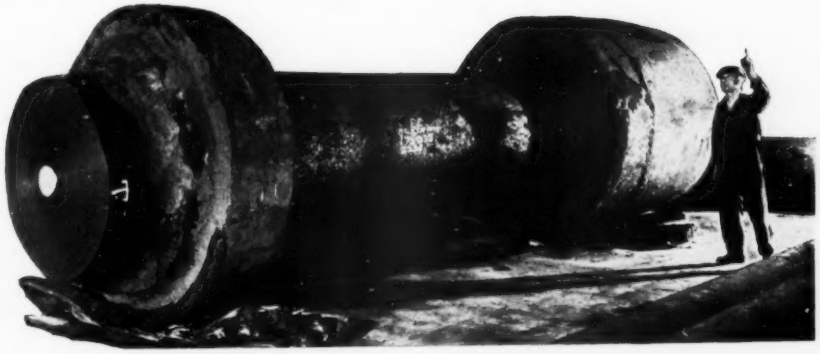
other forgings from ingots 30 cwt. and upwards—for all branches of engineering.

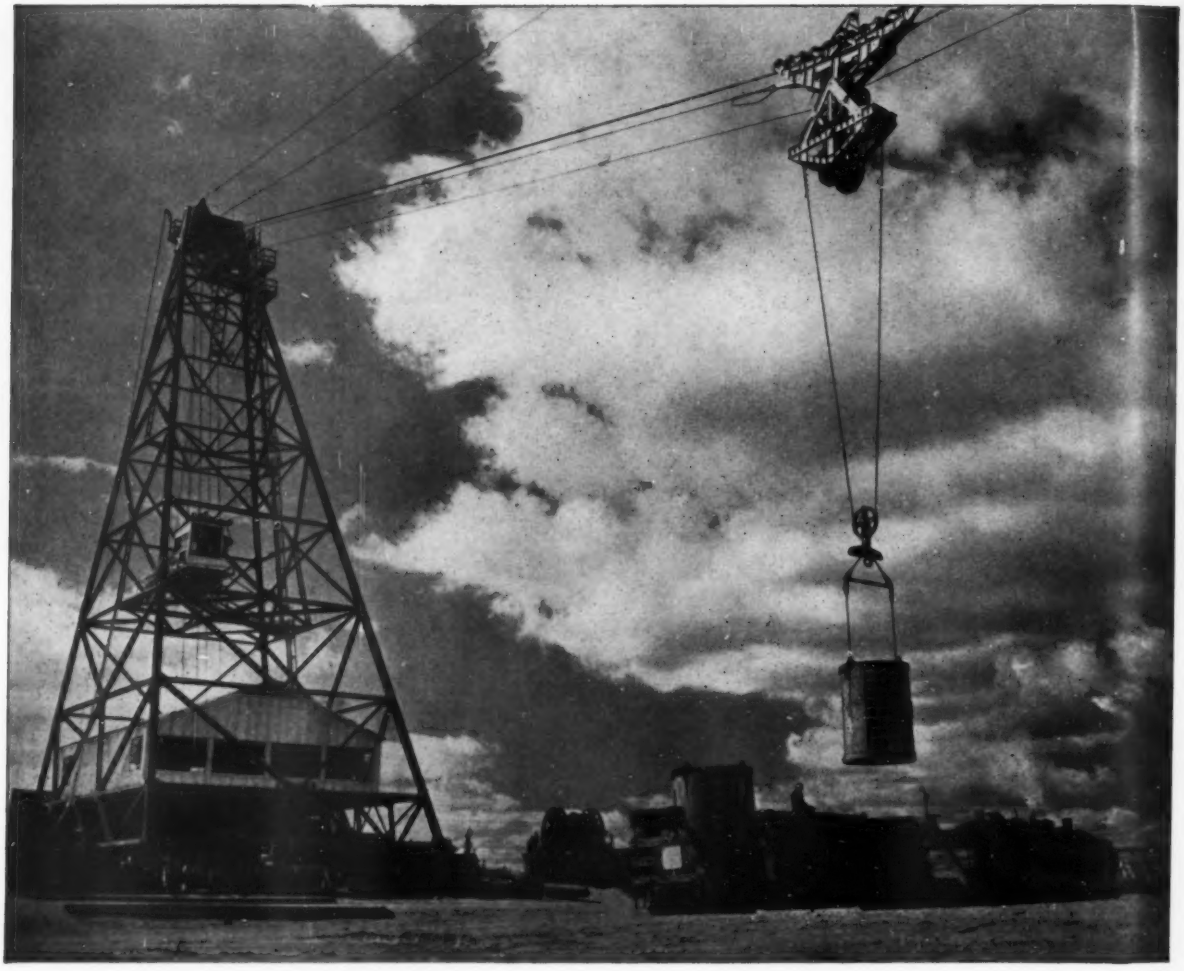
ENGLISH STEEL FORGE AND ENGINEERING CORPORATION LTD.

River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.

Illustrations show a forging operation under a 7,000 ton electro-hydraulic press, rough machined and black forged steel Turbine Shafts, 22′ 11″ long, 3′ 8″ diameter with 6′ 2″ and 6′ 4″ diameter couplings—weight as forged 111½ tons, rough machined 70 tons—for a modern hydro-electric power project.





20 ton 'TRAVELIFT' Cableway handling 8 cu. yd. capacity bottom discharge concreting bucket.

BRECO Ropeways and Cableways have been supplied and installed for operation under most extreme climatic and topographical conditions throughout the world.

BRECO — Sole manufacturers of 'Travelift' Cableways, outside the North American Continent. TRAVELIFTS are especially suited to high speed heavy construction work.

Literature available on request.

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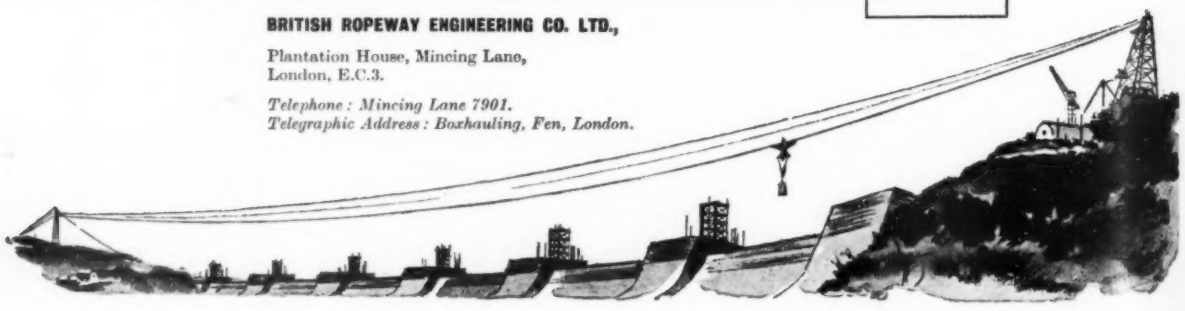
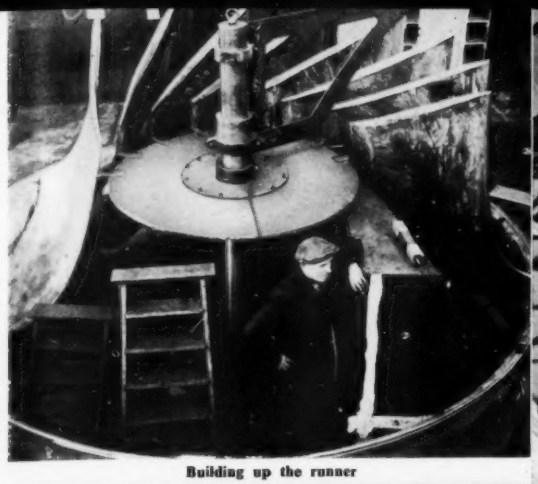
BRITISH ROPEWAY ENGINEERING CO. LTD.,

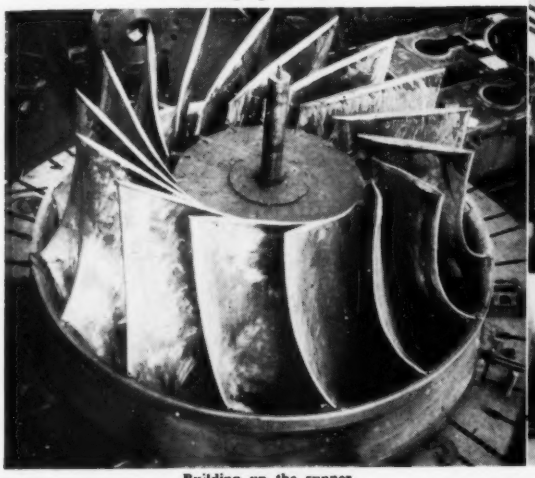
Plantation House, Mincing Lane,
London, E.C.3.

Telephone : Mincing Lane 7901.
Telegraphic Address : Boxhauling, Fen, London.

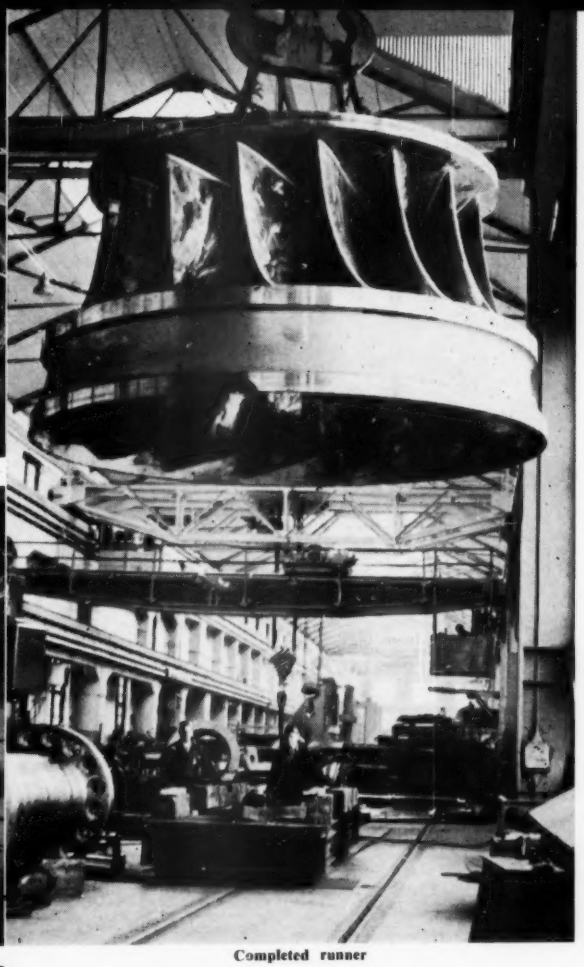




Building up the runner



Building up the runner



Completed runner

Welding the runner

Stress relieving furnace

The third KMW Turbine for the Swedish power plant Harrsele has now been put into service

With the installation of the third KMW turbine in the Harrsele Power Station, this plant has now been completed.

The first unit was put into service on August 15th, 1957, the second on January 29th, 1958, and the third on April 22nd, 1958. The total output amounts to 264,000 HP at a net head of 52.6 m (173 feet) and 125 r.p.m.

The runners are of welded construction according to our patented method. This construction ensures a better quality product and an improved hydraulic efficiency.

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Karlstad - Sweden

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.
607 Shell Tower Building, Montreal 2

PENSTOCKS
WATER GATES
HYDROELECTRIC
EQUIPMENT

CAP DE LONG: Self-hooped penstock for the Pragnères Power Station, in the Pyrénées.
Head 1,252 metres, Flow 14,6 cu.m./sec.
Diameter 2.25 to 1.60 metres, Power 200,000 H.P.

GRANGENT DAM on the Loire
One of the four Crest Gates, Sector Gate Type (12·5 m. x 14·4 m.) during erection.

ETABTS. BOUCHAYER & VIALLET
SOCIETE DAUPHINOISE d'ÉTUDES & de MONTAGES
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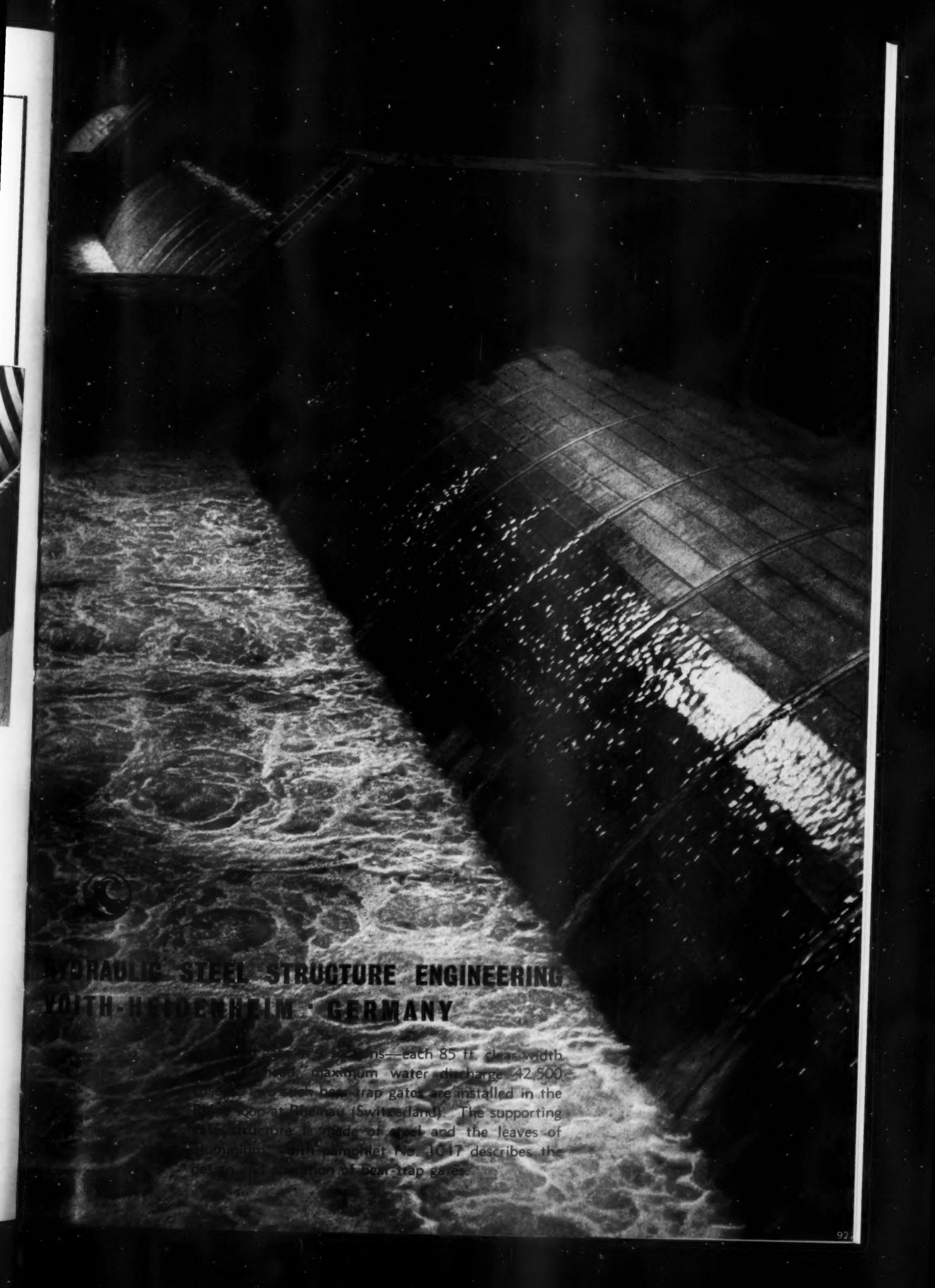
HYDRAULIC STEEL STRUCTURE ENGINEERING
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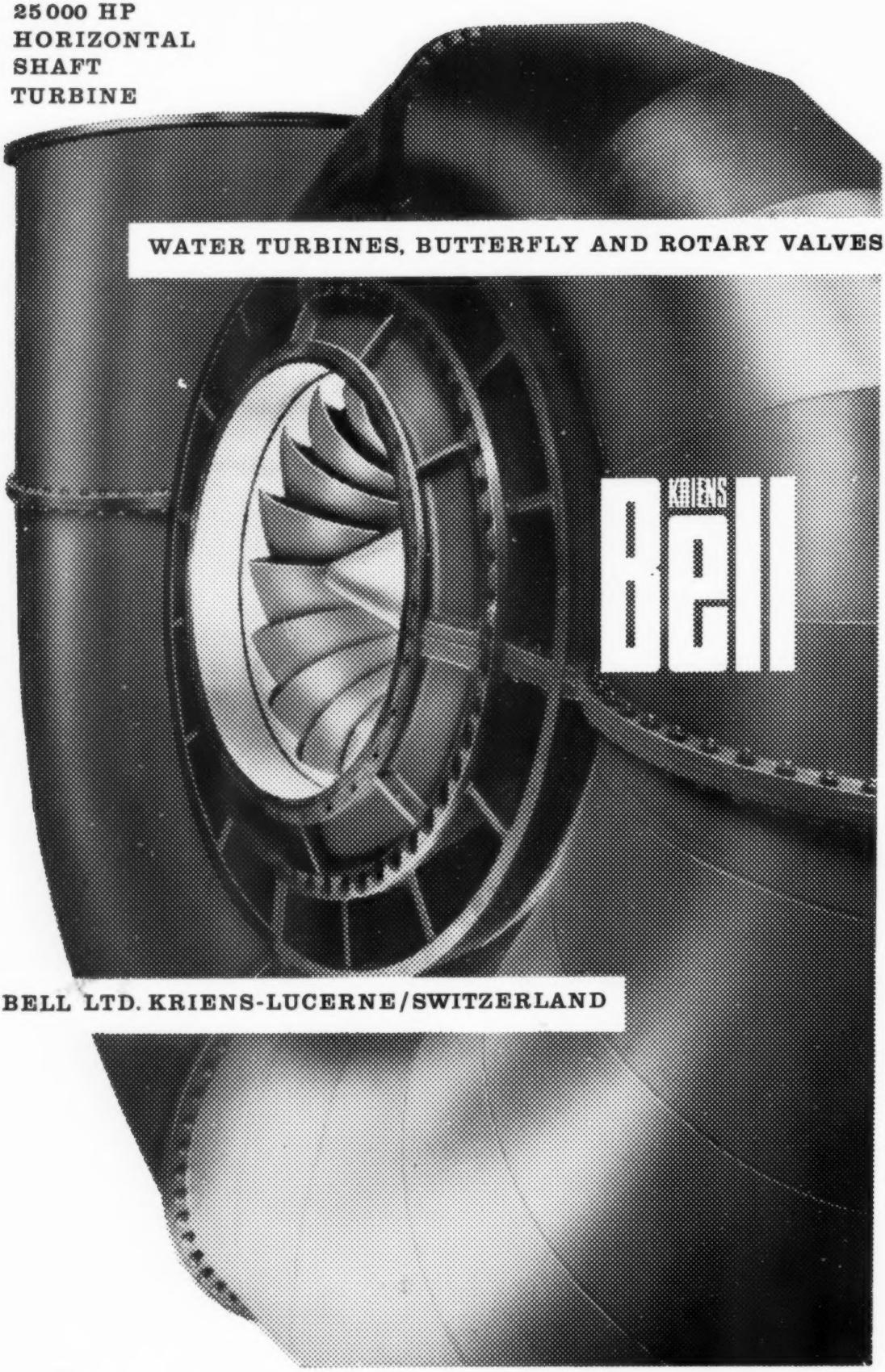
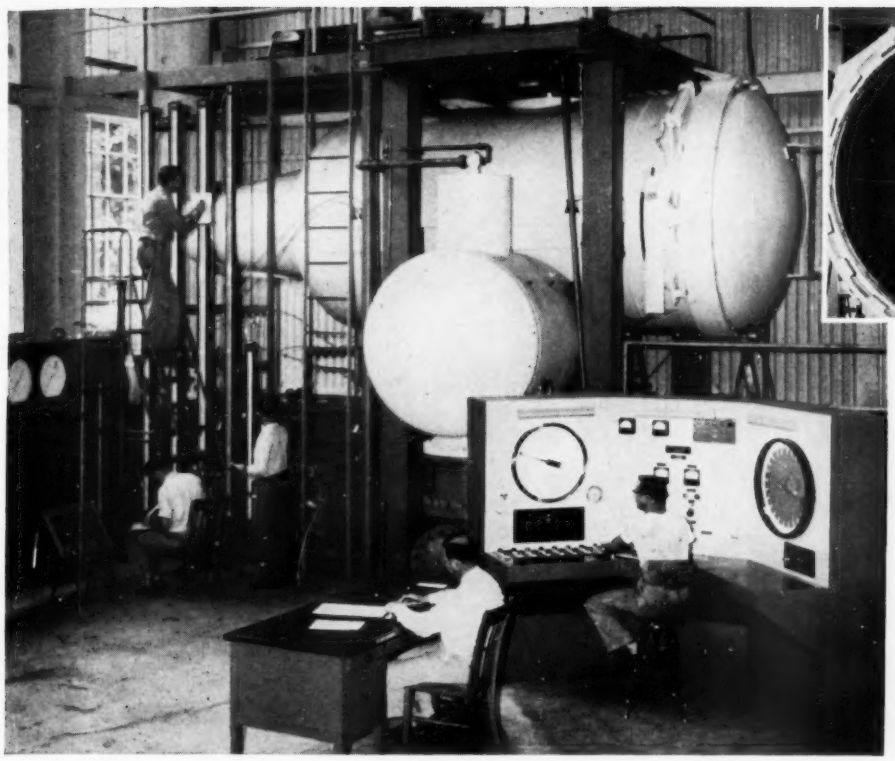
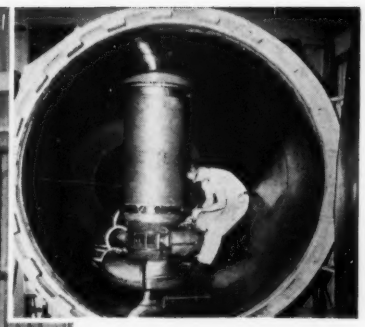
25 000 HP
HORIZONTAL
SHAFT
TURBINE







A complete model turbine wheel case assembly, built to extreme accuracy, is shown being mounted in the testing chamber.

New high head test stand in the SMS Hydraulic Laboratory, including control panel and gages.

High Head Turbine Test Stand At SMS Laboratory DUPLICATES FIELD CONDITIONS

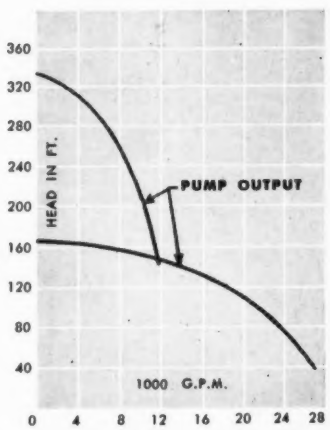
With the addition of its new high head test stand, the SMS Hydraulic Laboratory can now test homologous model turbines under controlled conditions that *duplicate* those found in the prototype installations. This is a substantial stride forward in hydraulic turbine research, since the complete reproduction of actual field conditions has not previously been possible.

The outstanding features of this new facility are:

- World's highest artificial testing head.
- Flows of 5,000 g.p.m. under 300-foot head, and 21,000 g.p.m. under 100-foot head.
- 300 H.P., 0 to 6,000 R.P.M., eddy current dynamometer.
- 100-ton water cooling system to maintain prototype water temperature.

Both basic research and formal contract acceptance tests are performed here. Test stand equipment permits testing of all Kaplan and Propeller, as well as many Francis turbine designs, under conditions of *head* and sigma that *duplicate* those found in the field. This provides a high degree of testing accuracy and permits accurate testing of settings that cannot be satisfactorily field tested.

For further information on the significance of this high head test stand, write to S. Morgan Smith Co., York, Pa.



Pump Head-discharge Curves for Series and Parallel Operation.

S. MORGAN SMITH

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Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
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ROTOVALVES
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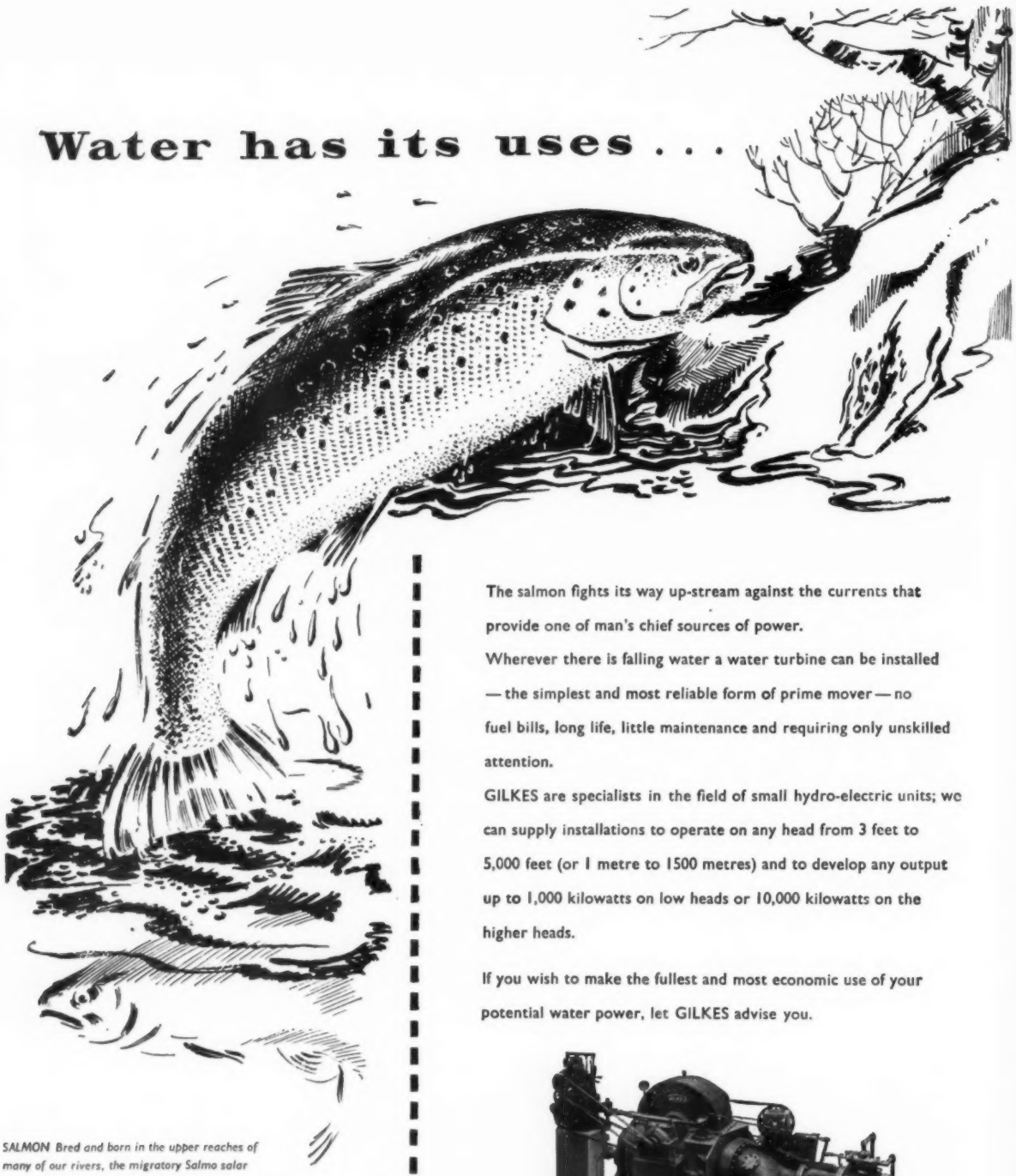
Water has its uses . . .



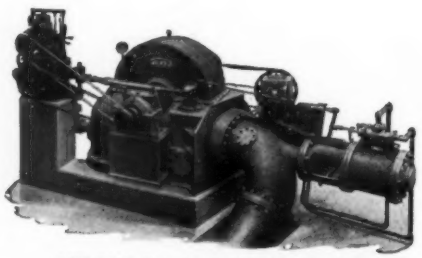
SALMON Bred and born in the upper reaches of many of our rivers, the migratory Salmo salar later seeks the sea, to live and flourish until it returns at last to breed. It makes its way up-river, covering long distances in very short time, fighting swift currents and small waterfalls, often to reach the very place where it was hatched some years previously.

The salmon fights its way up-stream against the currents that provide one of man's chief sources of power.

Wherever there is falling water a water turbine can be installed — the simplest and most reliable form of prime mover — no fuel bills, long life, little maintenance and requiring only unskilled attention.

GILKES are specialists in the field of small hydro-electric units; we can supply installations to operate on any head from 3 feet to 5,000 feet (or 1 metre to 1500 metres) and to develop any output up to 1,000 kilowatts on low heads or 10,000 kilowatts on the higher heads.

If you wish to make the fullest and most economic use of your potential water power, let GILKES advise you.



4,000 B.H.P. Turgo Impulse Wheel for Mauritius

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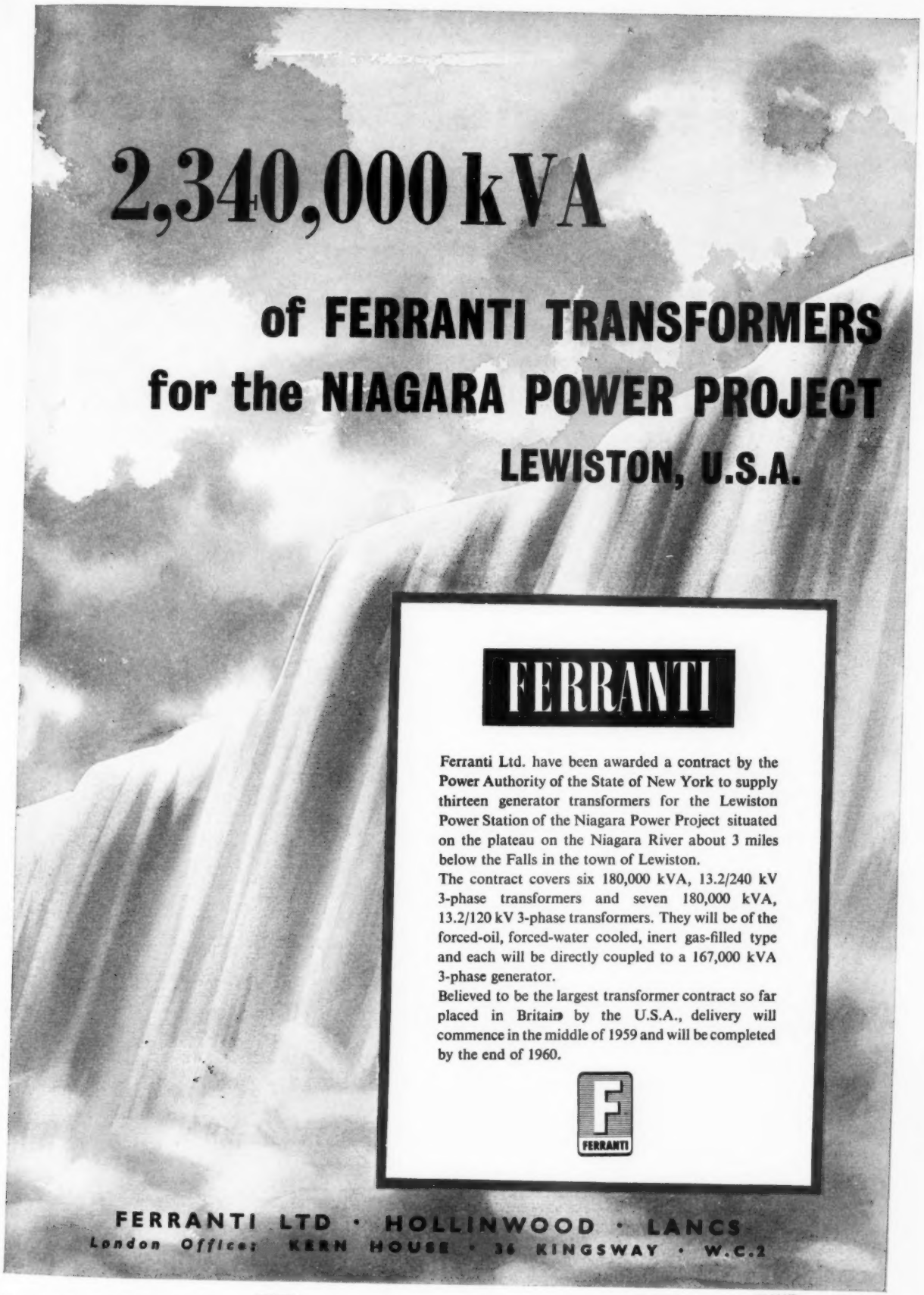
2,340,000 kVA
of FERRANTI TRANSFORMERS
for the NIAGARA POWER PROJECT
LEWISTON, U.S.A.
FERRANTI
Ferranti Ltd. have been awarded a contract by the Power Authority of the State of New York to supply thirteen generator transformers for the Lewiston Power Station of the Niagara Power Project situated on the plateau on the Niagara River about 3 miles below the Falls in the town of Lewiston.
The contract covers six 180,000 kVA, 13.2/240 kV 3-phase transformers and seven 180,000 kVA, 13.2/120 kV 3-phase transformers. They will be of the forced-oil, forced-water cooled, inert gas-filled type and each will be directly coupled to a 167,000 kVA 3-phase generator.
Believed to be the largest transformer contract so far placed in Britain by the U.S.A., delivery will commence in the middle of 1959 and will be completed by the end of 1960.
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FERRANTI
FERRANTI LTD · HOLLINWOOD · LANCS
London Office: KERN HOUSE · 36 KINGSWAY · W.C.2
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In Morocco . . . and the world over

Bucyrus-Erie excavators are preferred

In all parts of the world Bucyrus-Erie excavators are preferred for their output capacity and stamina.
Three 54-B diesel shovels with Torque Converter operate in this limestone quarry at Ain Sebaa on the outskirts of Casablanca. They maintain consistently high outputs loading rock for the manufacture of cement.
There is a size of Bucyrus-Erie heavy-duty excavator for your job also.

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RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

BUCYRUS ERIE

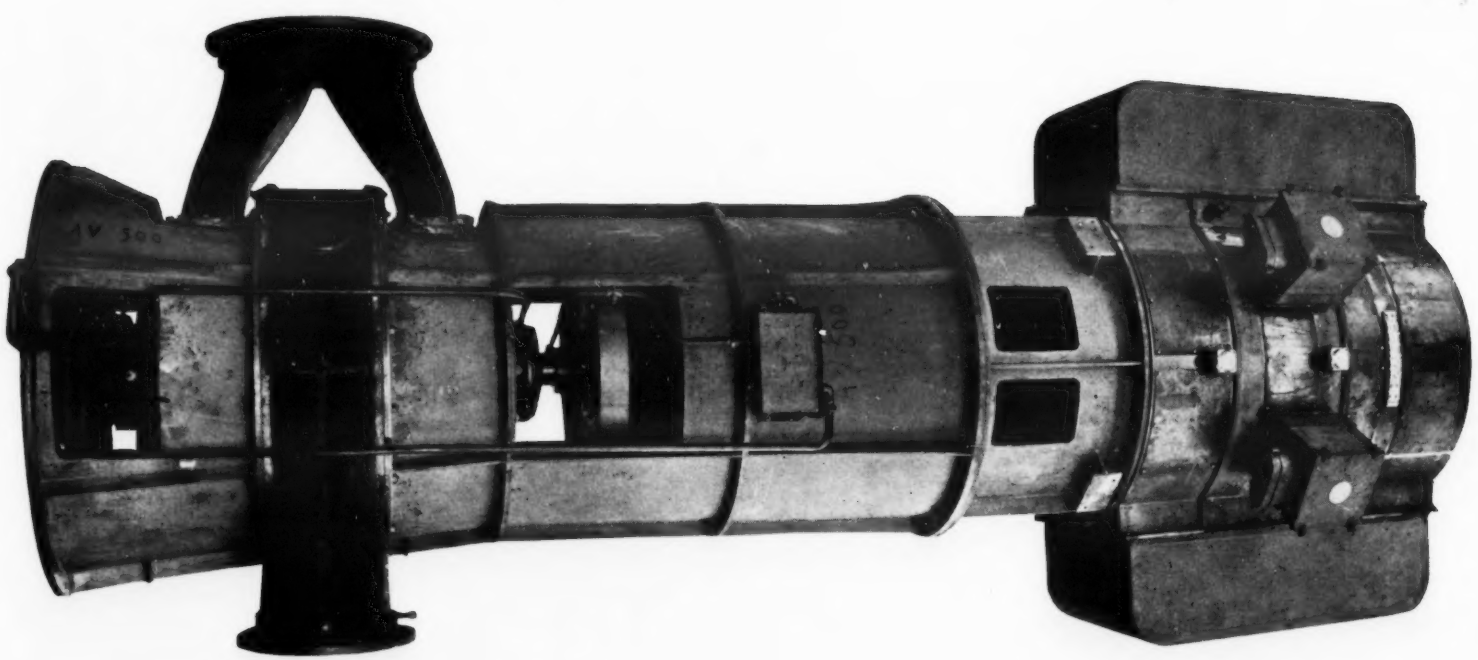
PELLIZZARI

ARZIGNANO ITALY

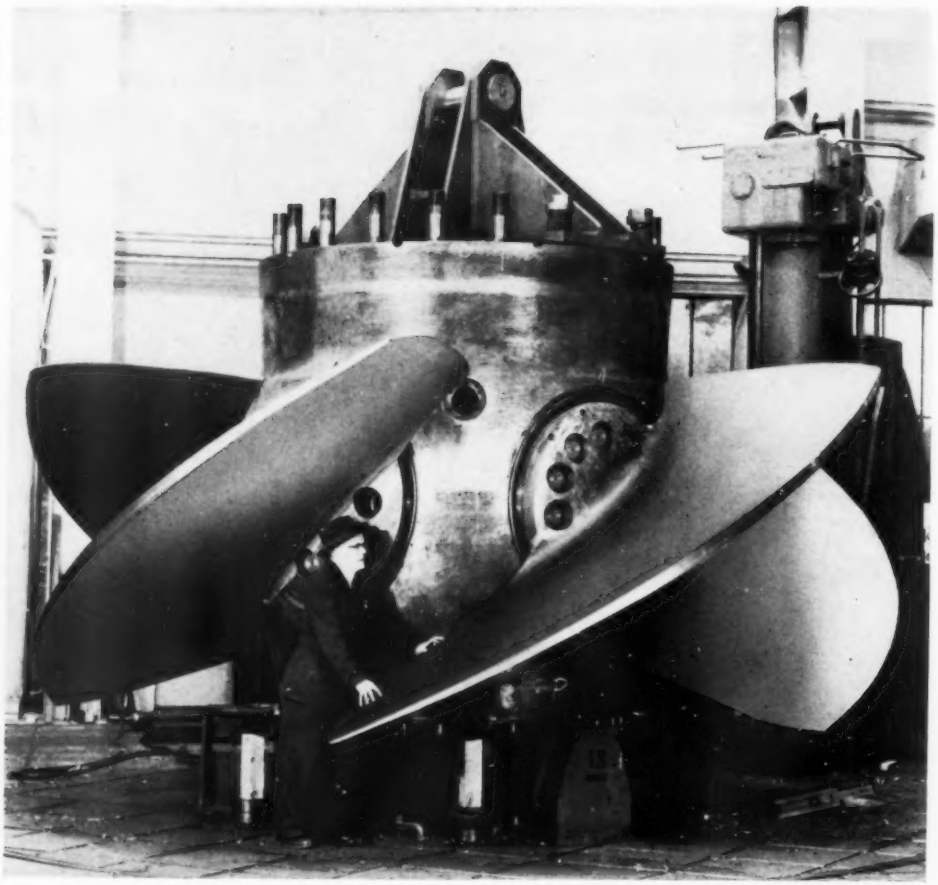
ELECTRIC AND HYDRAULIC MACHINES

MINISTRY OF COMMUNICATIONS AND PUBLIC WORKS ATHENS (GREECE) VILIZA PUMPING STATION

Pump Type AV 500 Capacity ft/sec. 1100 Total Man. Head mt 85
Absorbed Power h.p. 1450 Rated Speed r.p.m. 980
Driven by Electric Motor Type GASPV 1500/6 Rated Output h.p. 1700
Three phase Voltage Volt 3000 Frequency H_2 50
Rated Speed r.p.m. 980



Runner for The Panchet Hill Power Station. Runner diameter 5·4 m. (17 ft. 8 in.)



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Porsi, Sweden In service 1960	2 Kaplan	118·0	131,000	115	**These will be the most powerful Kaplans in Sweden.**
Mael, Norway In service 1957	1 Francis	140·4	47,500	150	**With regard to dimensions, the largest turbine in Norway.**
Panchet Hill, India In service 1958	1 Kaplan	81·0	56,000	125	**India's largest Kaplan, in output as well as dimensions.**
Rincón de Baygorria, Uruguay In service 1959	3 Kaplan	48·2	49,500	79	**With regard to dimensions, South America's largest turbines.**

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The above photo shows Casing for 150,000 HP Francis Turbine to be installed in the Bahkra Power Plant, India

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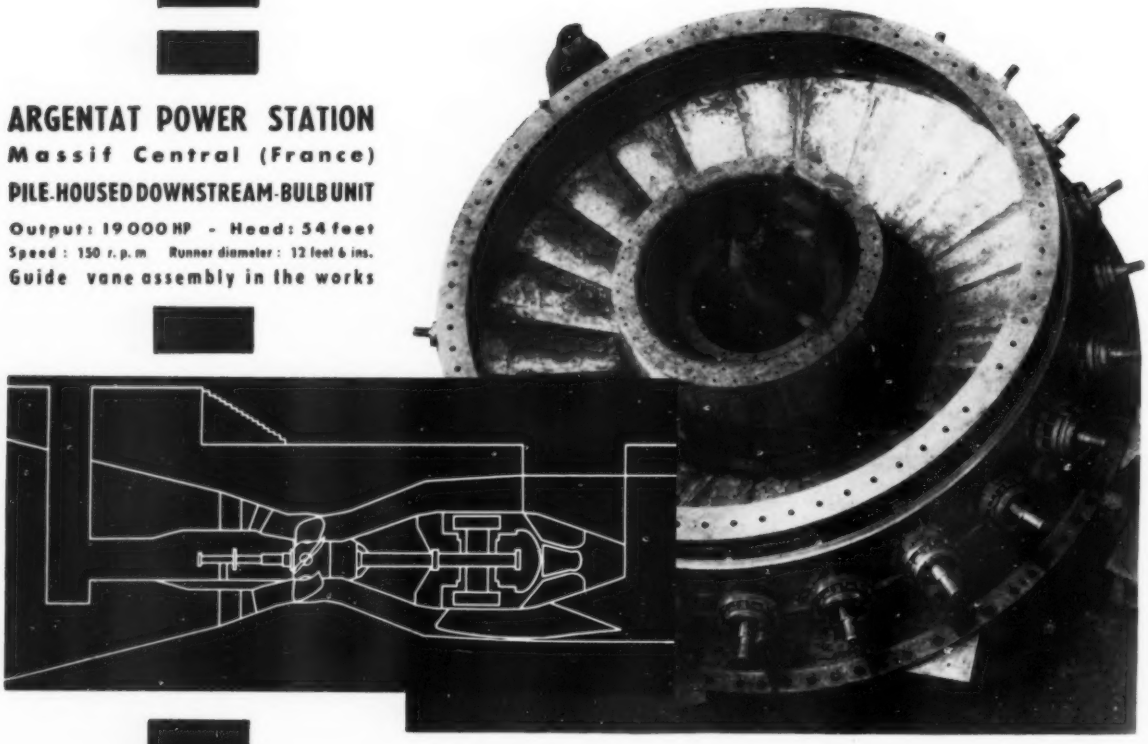

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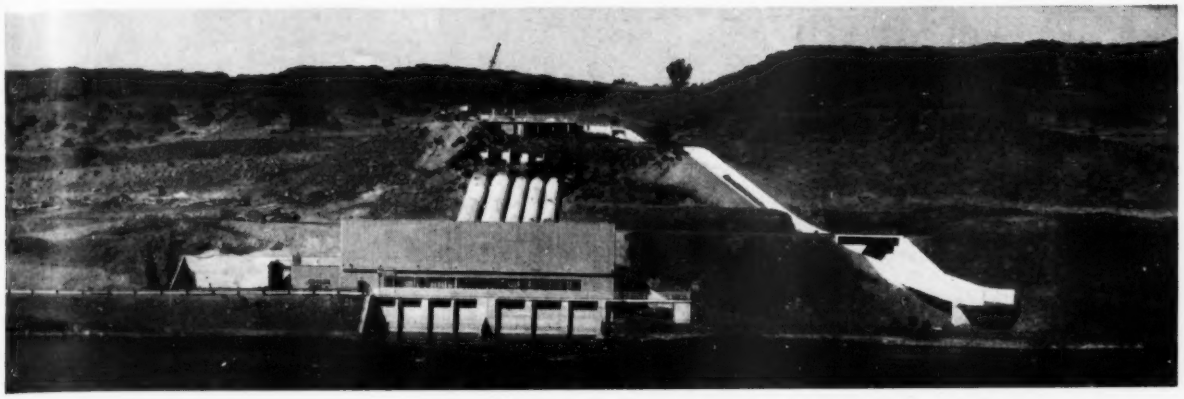

At the Bureau of Reclamation's Chandler Power and Pumping Plant, Leffel turbines drive both power and pumping units

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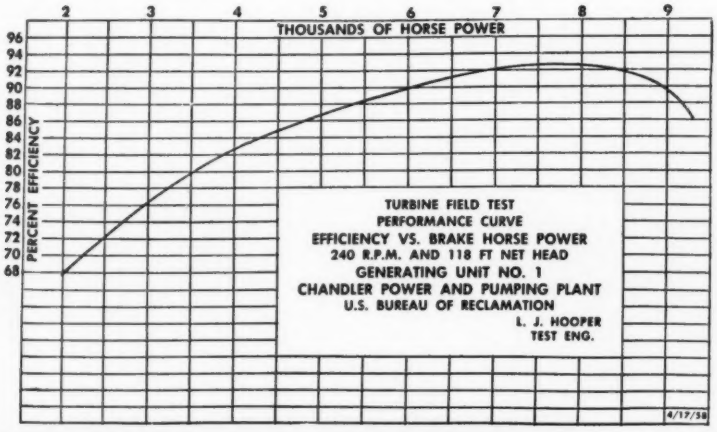

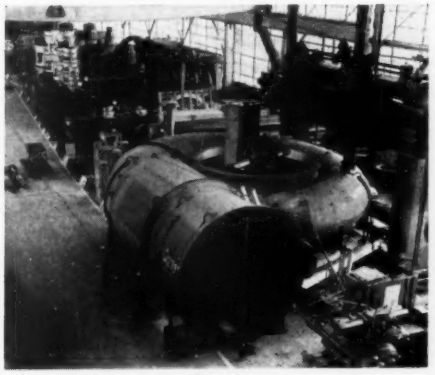

One of the spiral casings for the 8,500 HP turbines on Leffel's 24′ boring mill.

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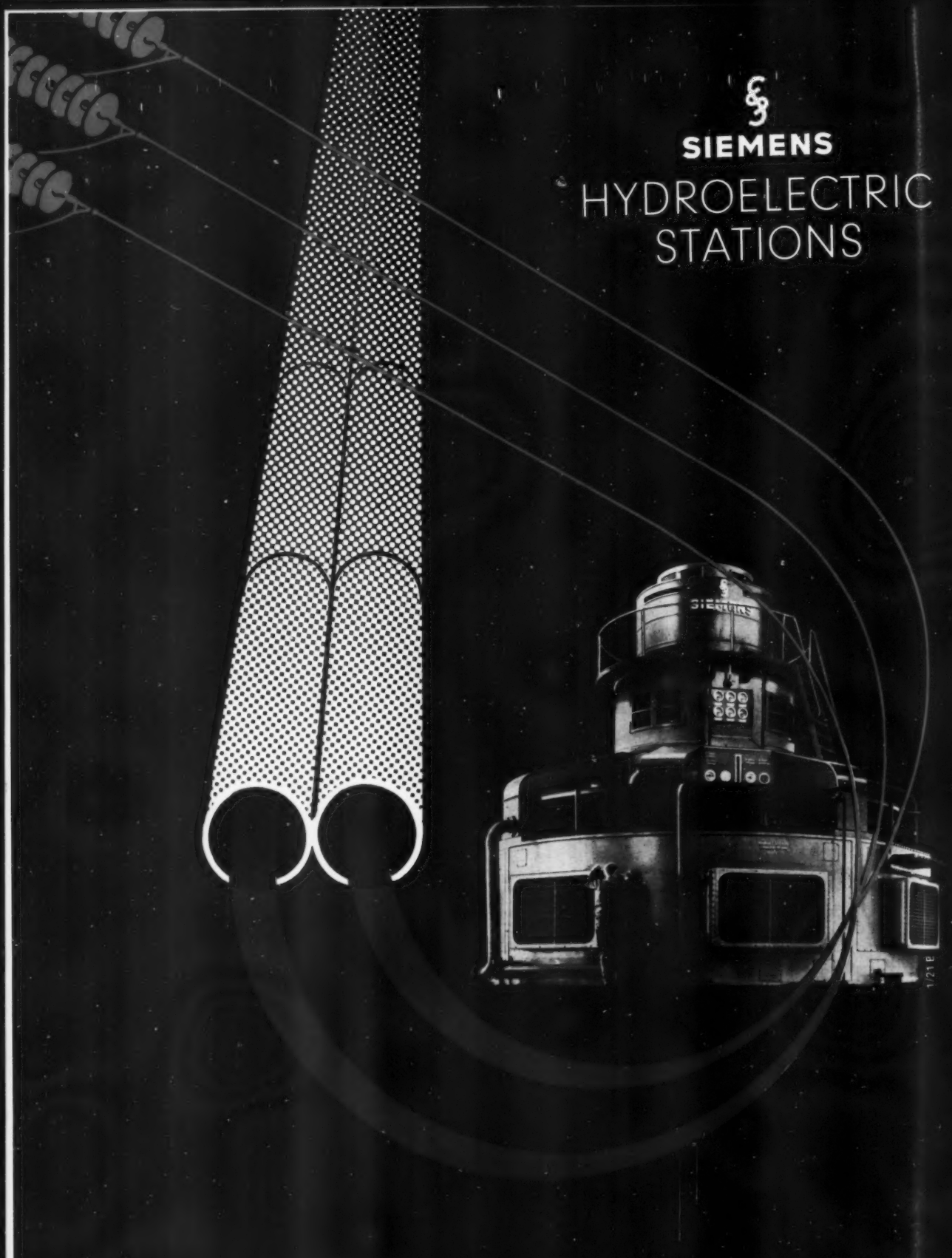

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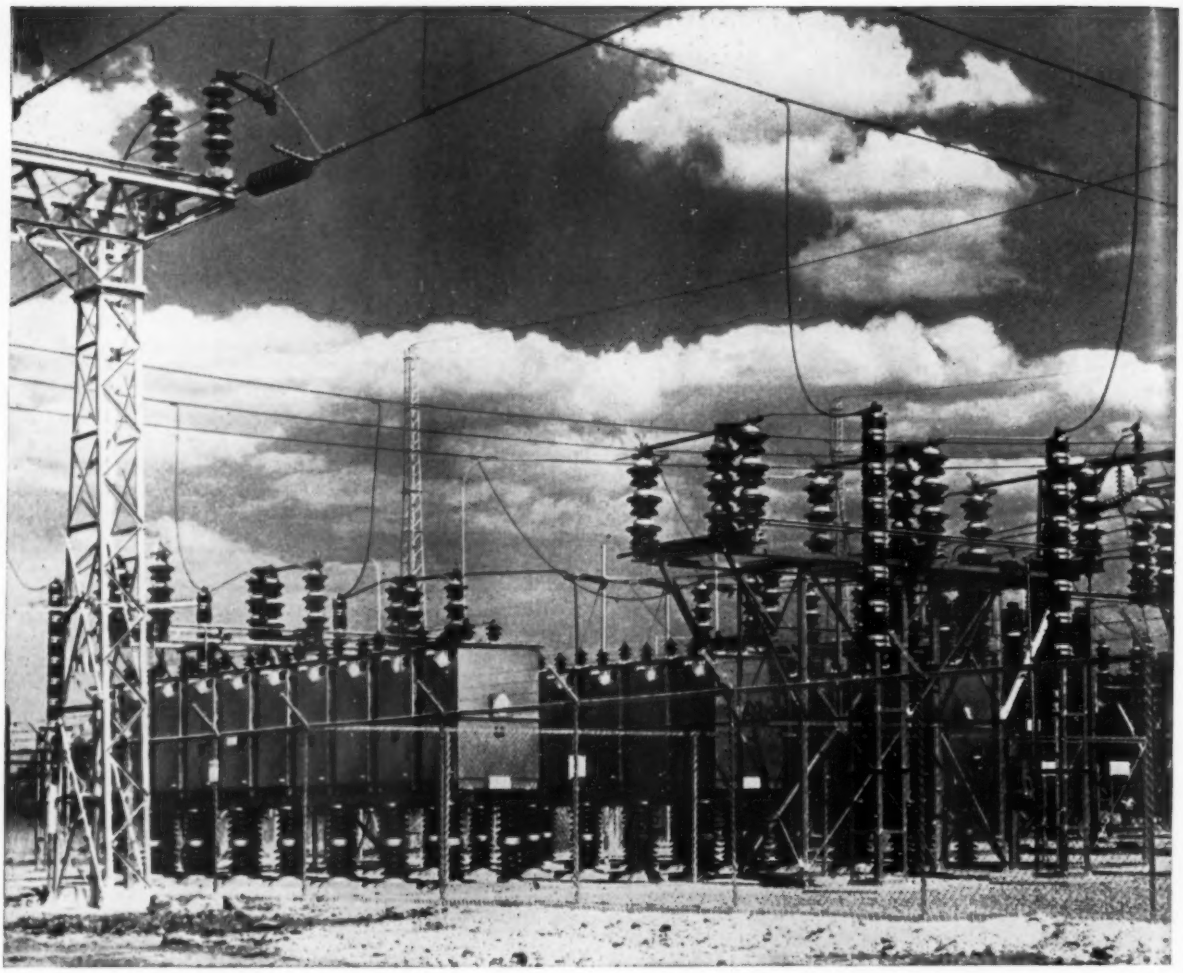

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This 6,000 kVAr capacitor bank at Hartley, Southern Rhodesia, is connected in series with the 90-mile Umniati-Norton 88kV transmission line.

The bank improves both regulation and stability, and the power transfer capacity of the line (within the limits of acceptable voltage drop) is doubled.

Although the use of series capacitors in transmission networks is comparatively new, their use is being rapidly extended. The Electricity Supply Commission of Southern Rhodesia is one of the pioneers in their application in the British Commonwealth, having 3 such installations. The Hartley installation was erected by the Electricity Supply Commission, BICC supplying all equipment and assisting in the planning and engineering of the scheme.

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British Contribution to World Hydro-Electric Progress

THE BRITISH ELECTRICAL POWER CONVENTION, which is held anually, is normally concerned with questions of electrical generation and developments primarily as they affect Great Britain, but the Tenth Convention, held in June, was of much wider interest. This was implicit in the theme of the Convention: "Electricity and World Progress: Britain's Contribution," which was developed by four important papers—two on nuclear energy by Sir Christopher Hinton and by Sir Claude Gibb, respectively, one on "Britain's Part in Electrical Development Overseas" by Mr. H. J. Beard, and one on "British Hydro-Electric Plant and World Power Requirements," by Messrs. J. C. Beverley, E. G. Teasdale and A. Wilmot. Naturally it is the last-mentioned paper which has the first claim on our attention, but a significant feature of the discussions throughout the Convention was the growing appreciation of the potentialities of pumped storage, particularly to provide peaking capacity in conjunction with nuclear and conventional thermal power plants. We shall return to this point later.

Although Messrs. Beverley, Teasdale and Wilmot are all members of the staff of The English Electric Co. Ltd., their paper presented the achievements of British manufacturers as a whole, and indeed, was so remarkably comprehensive that we cannot hope to do more than comment on a few salient points.

In the first place the paper revealed the amazing strides made in this field by British industry since the war, for after a period in which British contributions to hydro-electric development were on a small scale and lagged far behind those made by other countries they have now advanced to a point at which world records in many direcions are held by British manufacturers. Thus, up to 1920 the largest water turbine built in this country was only of 8,000 h.p. capacity; in 1922 the maximum size had increased to 30,000 h.p.; but what are now believed to be the most powerful hydro-electric generating sets in the free world are the British-designed 175,000 h.p. units at Bersimis I, and these are being surpassed by the 200,000 h.p. sets under construction for Chute des Passes. Further, the largest single order for turbines ever to be placed with a single manufacturer is claimed to be that for the 16 machines, each of 75,000 h.p., for the Canadian St. Lawrence Seaway station; the largest pump-turbine plant (although not containing the largest individual sets) is the six-unit installation at Sir Adam Beck No. 2; the highest-powered pumped-storage plant in the world is the 300 MW station now under construction at Ffestiniog, and this will contain the largest vertical-shaft pumps in the world; the largest fabricated turbine runners in the world are the 15 ft. 11 in. diameter units at Salto de Castro; and the record for the largest smooth-bore valves in the world, already held by the 11 ft. bore valves at Cabril and Castelo do Bode, is being surpassed by the 12 ft. bore valves now being made for Bersimis II.

Record hunting, however, has its drawbacks and may lead to false emphases, and the authors rightly paid more attention to the many British contributions to design, in both mechanical and electrical fields. We have only space here to mention the most outstanding contribution—the Deriaz turbine. This is a mixed-flow movable-blade Francis turbine, and it is a significant development in many respects. It is suitable for heads up to 600 ft. and thus greatly extends the range of the Kaplan-type machine; indeed its efficiency curve is even better than that of the Kaplan. Further, it is ideally suited for use as a reversible pump-turbine—as at Sir Adam Beck No. 2—for it can be started under water, and quantitative regulation as a pump as well as when functioning as a turbine can be obtained by adjusting the movable runner vanes, the usual wicket gates being dispensed with in many cases.

Mention of this machine in the paper naturally led

to an account of pumped-storage schemes engineered by British manufacturers, but an appraisal of the scope of pumped storage was left to the discussion. Mr. D. Clark of the Central Electricity Generating Board made a particularly useful contribution. He pointed out that pumped storage could reduce the amount of running spare and hot spare thermal plant that had to be kept available, but if pumped storage were installed in place of new high-efficiency thermal plant the saving in overall fuel consumption effected by such plant would be lost. The capital cost of modern steam plant was of the order of £45 per kW, and the incremental cost of pumped storage would have to be less than £40 per kW to justify it. To achieve this it would be necessary to resort to larger unit sizes, and he contemplated pump-turbine units as large as 200 MW, although some other speakers had envisaged a limit of 100 MW. This need to reduce the capital cost of pumped-storage plant was stressed by other speakers, and Mr. Wilmot, in presenting this part of the paper, referred to the urgent need to develop the high-head reversible Francis pump-turbine in which the pump and turbine characteristics could be matched without resorting to a dual-speed electrical machine. The balancing of pumped-storage against thermal or nuclear capacity in a combined system can be complex, and our readers will have noted Dr. Jaeger's important contribution to this analysis in the article which we conclude in this issue.

Hydro-electric development is of worldwide importance, and as the existence of this journal demonstrates, is most truly viewed from an international standpoint. Engineers in most, if not all, of the countries mainly concerned have achievements to their credit of which they are justly proud. It is in no spirit of disparagement of such achievements that we have ventured to refer at some length to a paper that aims to place on record a fact that is not everywhere appreciated—that in the hydro-electric field British manufacturers and consulting engineers hold a prominent place in the van of progress.

British Columbia Contract

B.C. ELECTRIC have announced that contracts totalling $6,000,000 have been awarded for the construction and installation of twin penstocks, 4,900 ft. long and 9 ft. in diameter, for the Bridge River project, 13 miles west of Lillooet. The penstocks will be fabricated in 40 ft. lengths and will be manufactured by the Vancouver Iron Works and the Dominion Bridge Co. Ltd., and the entire installation job will be carried out by the latter company. The penstocks will carry Bridge River water to the No. 2 power house on the shore of Seton Lake from the downstream end of a 2¼-mile tunnel built under Mission Mountain. The total weight, including the 400 ft. of tunnel liner for the Seton Lake end of the tunnel, will be 11,566 tons. The construction of concrete footings will be completed in the autumn by Northern Construction and J. W. Stewart, general contractor for the No. 2 Bridge development.

Other phases of the $56,500,000 project are well advanced. Mission dam on the Bridge River is one-third complete; 9,500 ft. of the 12,500 ft. tunnel have been drilled and the concrete foundation for the power house is 70% complete. Two of the project's four generating units will be ready for service by the autumn of 1959. The project will add 345,000 h.p. to B.C. Electric's generating capacity.

Power Possibilities in Lower Mekong Basin

IN publication No. 12 of the Flood control Series issued by the United Nations, a broad scheme of development for the Mekong river is outlined to secure hydro power, flood control, improved irrigation and inland navigation facilities. The river involves the wellbeing of three countries, Viet-Nam, Cambodia, and Thailand, all of which have to pay a high price (5 to 30 U.S. cents per kWh) for electrical energy, most of which is generated by diesel plants. The present installed capacity at Bangkok is 68MW and a further diesel plant nearing completion will add a further 10 MW to this total. On the other hand, the Bhumibol multi-purpose project on the Yanhee gorge on the Ping river is planned to develop 560 MW and to supply power at 2 U.S. cents per kWh. The Da Nhim project is estimated to have a capacity of 72 MW in the first stage and an ultimate capacity of 300 MW. Other sites considered worth investigation are situated at Luang Prabang, Pa Mong, Khemarat, Khone, Sambor and Nam Theun.

As the Mekong basin is endowed with rich mineral deposits—iron ore, gypsum, bauxite, tin—and is capable of producing immense quantities of soft wood and bamboo, which are suitable for papermaking, there would be no difficulty in finding a market for the large power potential available.

Keepit Power Station, New South Wales

THE Harland Engineering (Australia) Pty. Ltd., of Melbourne, are to supply and erect the equipment to be installed in the Electricity Commission of New South Wales' Keepit power station and associated sub-station. The plant comprises a 6,000 kW hydro-electric generating unit, valves, pumping equipment, crane, draft-tube gates, transformer, switchgear, control gear, remote supervisory equipment, batteries and cables. The power station is being built at the foot of Keepit dam which spans the Namoi river about 200 miles due north of Sydney; the water will subsequently be used for irrigation purposes. This power will be fed via a 66 kV transmission line into the Commission's interconnected network. The generating unit will be remotely controlled from the Newcastle control centre, some 140 miles away, and will normally be run over the morning and evening peak periods, although there will be long periods when it will run continuously. When the unit is not generating it can be operated as a synchronous condenser at full output.

The 8,500 h.p. vertical-shaft, Francis-type water turbine and the direct-coupled, 7,500 kVA water-cooled synchronous generator are to be manufactured by the Harland Company's augmented works in Scotland, which was specially built for the construction of large hydro-electric units. The turbine is designed for a head-range of 62/123 ft., the generator being arranged for supplying 3-phase current at 11 kV and 50 cycles. Owing to the low head the

machinery is physically large although the output is relatively small. The head-range is very wide for this type of turbine and great care was taken in its design to provide satisfactory operation and performance under such onerous conditions.

Economic Survey of Alberta

A COMPREHENSIVE survey of the economic potential of Alberta has been prepared by J. T. Donald & Co. Ltd., Research Consultants, on behalf of Calgary Power Ltd. The report was presented to a meeting of the Chamber of Commerce, Calgary, which was attended by the United Kingdom Trade Mission, headed by Sir William Rootes, Chairman of the U.K. Dollar Export Council. The report deals with all aspects of the expanding activity in the Province and refers to hydro-electric plants as being able to assure low-cost power for industry for some time to come. Several million kW of undeveloped capacity still remain within transmission range of the electric load centres and this circumstance, combined with an abundance of low cost fossil fuel for thermal plants, puts Alberta in a particularly favourable position in regard to meeting power requirements for many years to come. In the future the trend will be to meet base-load demand with thermal plants and to use the existing and potential hydro sites to provide cheap peaking capacity.

Further Snowy Mountains Contract

THE American firm, Henry J. Kaiser Company, has signed as a joint venture a contract worth nearly £A18 million for work on the Snowy Mountains hydro-electric project in south-eastern Australia. Joint partners in the venture include Morrison-Knudsen Company of Australia and three other corporations with headquarters in the U.S.A.

The new project includes a concrete diversion dam, a power station, two tunnels and extensive other works. Operations started in June. The new concrete dam will be 150 ft. high and 390 ft. long. The tunnels, which are 25 ft. in diameter, will have an ultimate length of seven miles.

Mechanical Engineering Research

IN a report entitled "Mechanical Engineering Research, 1957," it is stated that in the decade since the Laboratory was founded spectacular industrial developments, some of them in new fields, have underlined the need for intensive research on a much larger scale if Britain is to keep her place in the world. The report deals with the work of the D.S.I.R.'s Mechanical Engineering Research Laboratory at East Kilbride, Glasgow, and puts forward proposals for the future development of the Laboratory accordingly.

Examples are given of the kind of research which the Board consider to be urgently needed and include investigations into the physical properties of existing materials and the production of entirely new materials by changing crystal structures, for meeting the demands of the higher temperatures and pressures now encountered in industry. More directly related to hydro-electric engineering practice are the researches being carried out on pumps for pumped-storage schemes, particularly when the turbine is used in reverse as a pump. It is considered that the matter of blade design should be given high priority as it is clear that the need for pump storage will grow with the erection of nuclear plants. Another interesting line of research is concerned with the field measurement of water flow; four methods have been investigated so far—the propeller current-meter method, pitot tube traverses, the salt-velocity method and the salt dilution method. Following the laboratory work on these methods, all four have been tried out simultaneously in a 40 in. diameter pipeline at the Kinlochleven hydro-electric station. It was concluded that none of the methods possessed any outstanding superiority compared with the others because each had certain advantages for specific applications when cost, ease of installation, speed of evaluation of results, as well as accuracy, were taken into account. The field tests have also shown how the working teams can get the best results as quickly as possible. The Report is published by H.M.S.O.; price 4s. 6d. (81 cents U.S.A.), by post 4s. 10d.

Oberhasli Development

FOLLOWING the commissioning on January 30, 1958, of the third generating set at the Handeck II power station of the Oberhasli development, the fourth set has recently been put into operation. Together with the two 41,000 hp. sets installed at the initial stages in 1947 and 1950, Handeck II can now supply to the KWO concern a total of 420 MW from the Innertkirchen busbars.

Chute-des-Passes Pressure Tunnel

PRESSURE tunnel crews working two shifts daily at the Chute-des-Passes power development in Northern Quebec are pushing ahead at the rate of almost 200 ft. per week at each of four headings, one crew having made a 222 ft. advance in the one week period. The six-mile tunnel is a fundamental element in this million h.p. project which will increase the hydro-electric power resources of the Aluminum Company of Canada, Limited, in Quebec to 3,580,000 h.p. The scheduled date for power production is August 1, 1959. Construction crews, who worked through minus 50°F. winter conditions, went underground at the first of the three adits on October 31, 1956, and reached the main tunnel line April 17, 1957.

Trucks are now removing 6,500 cu. yards of tunnel muck from each heading per week at the rate of 33 cu. yards per foot of face. The top heading and bench method is being employed, large drill jumbos, each fitted with 21 drills, being used at each heading. Removal of the bench is expected to progress even faster than work on the top heading sections.

Simultaneously, in the No. 3 adit, which gives access to the powerhouse area, miners are working at five additional headings—the power-house roof, draft manifold roof, draft tubes, penstock manifold and tailrace tunnel.

Perini-McNamara-Quemont Construction Companies, a joint venture, are employing 1,580 men on the job. Associated contractors have about 300 men on their payrolls. When completed, the 31,000 ft. of main tunnel, 35 feet in diameter, will be lined with concrete.

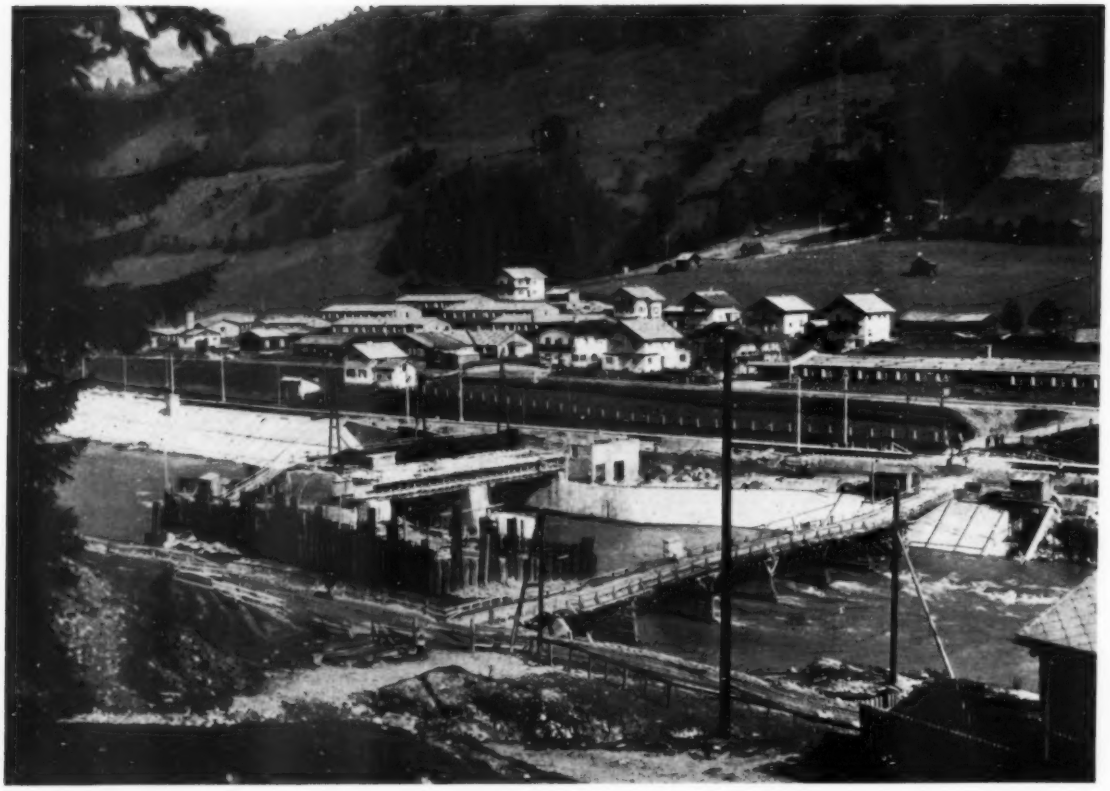

Fig. 1. The Gries intake under construction

Tauernkraftwerke A.G. Development Programme

Dr. E. Königshofer gives an outline of developments on the Salzach, Zemme and Gerlos rivers which are under construction or projected by Tauernkraftwerke A.G.

EVEN before the completion of the Glockner-Kaprun scheme* the Tauernkraftwerke A.G. initiated the construction of a new power plant at Schwarzach on the Salzach river. It may be recalled here in the Glockner-Kaprun scheme the water of the Kaprun river, which flows down the northern slopes of the Tauern massif and later joins the Salzach river, is utilised by way of two storage reservoirs, viz., the Mooserboden and the Wasserfallboden. In addition, water is diverted from the Möll river running southwards from the Tauern mountain chain and conducted to the Mooserboden reservoir through a 7·2-mile-long tunnel. Thus, a power plant erected on the Salzach river can rightly be termed an annual storage plant since it utilises the waters of the two above-mentioned storage reservoirs although it does not dispose of a storage reservoir itself. Actually, the Schwarzach plant now under construction will be equipped only with a small daily pondage basin, and during periods when the Kaprun water is stored the Schwarzach plant will utilise primarily the water flow of the Salzach river and be operated as a run-of-river plant.

Work on the Schwarzach plant (Fig. 1) is well advanced. The 10-mile-long tunnel was holed through on October 25, 1957, and partial operation may be expected to begin on the 1st of October of this year. When fully developed, the plant will have a generating capacity of 120 MW, yielding an annual produc-

* *See* WATER POWER, August and September, 1954, pp. 298 and 331.

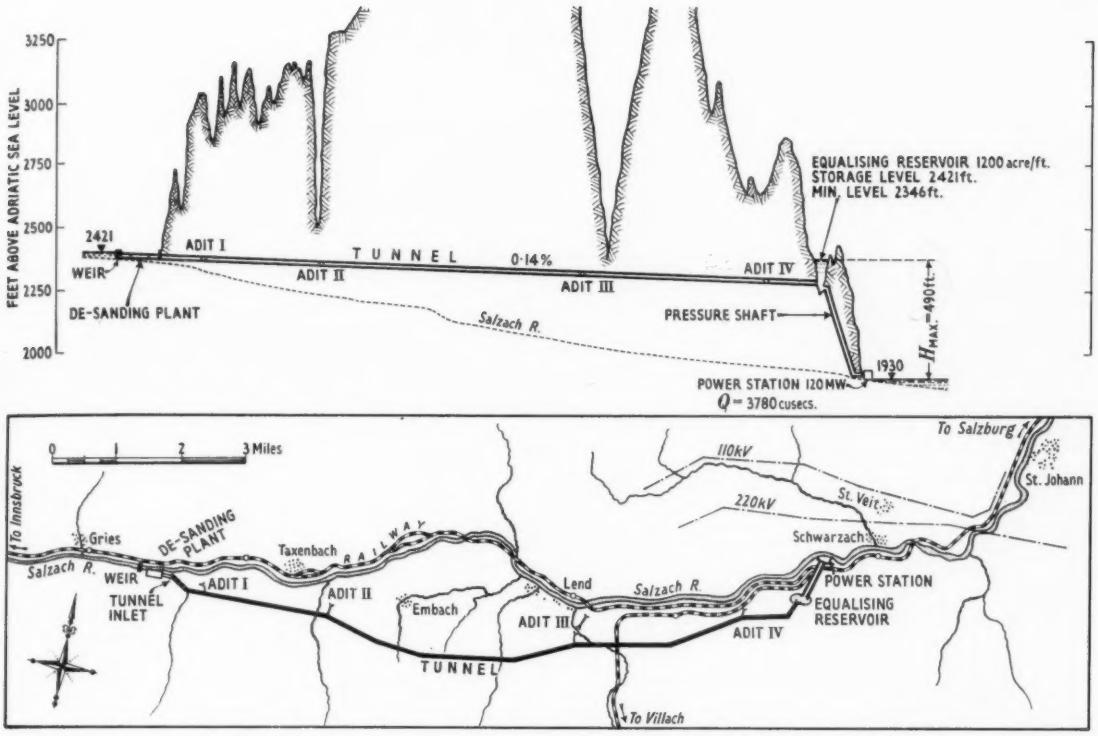

Fig. 2. Profile diagram and map of the Schwarzach development

tion of 482,000,000 kWh, of which 166,000,000 kWh will be generated in the winter months. Fig. 2 shows the plan view and the longitudinal section, while Figs. 1 and 4 are various views of the plant, which is nearing completion.

Thorough studies undertaken by the Tauernkraftwerke A.G. have revealed that the Salzach river may be economically developed in four further stages, and altogether eight generating units with an aggregate capacity of 205 MW could be installed, on the basis of which 940,000,000 kWh could be generated annually, 320,000,000 kWh in the winter months. These plants would also utilise the water collected in the Mooserboden and Wasserfallboden reservoirs and could thus be operated as storage plants.

Zemme River Project

Detailed studies concerning the utilisation of hydropower resources in the adjacent catchment area in the Federal Province of the Tyrol apportioned to the Tauernkraftwerke A.G. have revealed the possibility of constructing a group of power plants in which even greater capacities could be concentrated and more peak energy obtained than in the Salzach group. The Tauernkraftwerke A.G. is therefore actively promoting the realisation of another project now ready for construction, viz., the Zemme river project, and has postponed the further development of the Salzach river to a later date. A plan view and longitudinal section of the Zemme development are given in Fig. 5.

At the point where the Schlegeis mountain stream joins the Zams river at a height of about 5,200 ft. above sea level, conditions are suitable for the construction of a storage reservoir with a volume of 75,000 acre-ft.; 20% of the catchment area is glaciated. Geological conditions for erecting a gravity arch dam, 380 ft. high, with a crest 2,000 ft. long and requiring 1,180,000 cu. yards of concrete are very favourable. Full use can be made of the storage basin by diverting water into it from the Zemme river through a tunnel 3¼ miles long, whereby the catchment area of the dam site is increased from 23 to

Fig. 3. Pipe tunnel, showing space for two penstocks below and entrance to lower valve chamber above

Fig. 4. Schwarzach power station under construction

43 sq. miles, and thus full utilisation of the whole storage basin is ensured even in dry years.

The available water volume will be utilised in a power station at Rosshag to which the headwater is conducted by way of a pressure tunnel about 5 miles long and 15 feet in diameter, into which several streams are diverted. Then follows an armoured pressure shaft, almost half a mile long and having a diameter of nearly 10 ft., which is connected with the power station through an armoured pressure tunnel, 650 ft. long.

In the Rosshag power station four 50 MW generating sets, each driven by a vertical counter-pressure Francis turbine, will be installed and will discharge into a 5 mile pressure tunnel. Several such streams will be diverted into this tunnel so that the whole catchment area will be enlarged to 100 sq. miles. This tunnel discharges to a weekly pondage basin at Stillup, which will be closed by a 69 ft. dam and will have a capacity of 3,650 acre-ft.

The Stillup pondage basin will be connected with a power station at Mayrhofen through a pressure tunnel about 2 miles long, having a diameter of nearly 16 ft., and two armoured penstocks 0·65 mile long. In this power station four 40 MW generating units will be installed, each generator being equipped with two horizontal Pelton wheels.

The generating units to be installed in Rosshag power station will provide a capacity of 200 MW, whereby on the basis of a utilisable flow of 1,500 cusecs 143,900,000 kWh can be generated in winter and 70,900,000 kWh in summer, or altogether 214,800,000 kWh per annum. If, however, two of the four generating units are equipped with pumps and provided that during the lower-rate periods surplus energy is available, as may be justly assumed, an additional 29,200,000 kWh could be produced in the winter half-year and 110,000,000 kWh in the summer half-year. Lower rate periods may be taken as being from 22·00 hours to 6·00 hours in all nights throughout the year, and from Saturday 13·00 hours to Sunday 22·00 hours in summer.

Thus through a pumping operation the available annual energy is increased to 354,000,000 kWh (winter 173,100,000 kWh and summer 180,900,000 kWh).

For the Mayrhofen power station, which will also dispose of a utilisable flow of 1,500 cusecs, the installation of pumps is not envisaged, and its annual power production will amount to 364,000,000 kWh (143,100,000 kWh during the winter and 220,900,000 kWh during the summer).

Thus the entire power-plant group, in the case of pumped storage, will yield a power production of 316,200,000 kWh during the winter and 401,800,000 kWh during the summer or altogether 718,000,000 kWh per annum.

The performance of the development just described suggests a comparison with Glockner-Kaprun. If pumped storage is disregarded in both cases, the energy production of the Zemme development

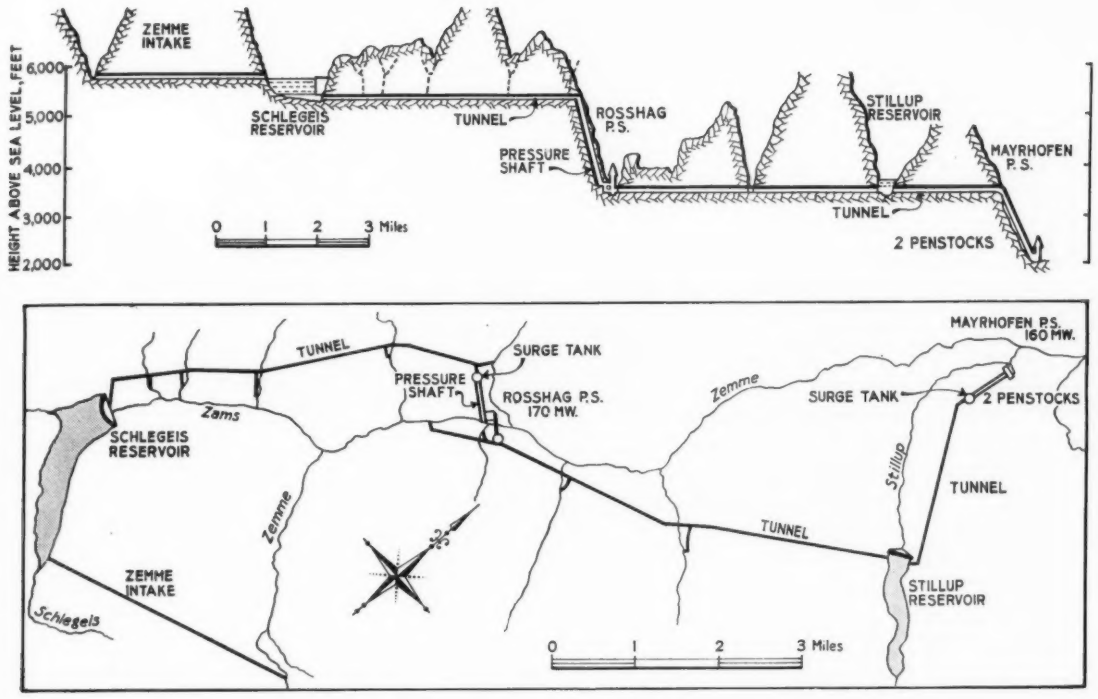

Fig. 5. Profile diagram and map of Zemme river project

amounts to 94% of that of Glockner-Kaprun, whereas if pumped storage is included, the percentage falls to 88%. But in the project under consideration the energy obtained annually is more evenly divided up between the winter and the summer, the ratio in the case of Glockner-Kaprun being 76% winter and only 24% summer energy.

Gerlos Development

During the years 1938–1945 Austria was a part of the German Reich, and Austria's hydro-power resources were developed to the greatest possible extent for strengthening Germany's war potential. Many building sites were established but only few plants were completed. In 1939 development was begun of the Gerlos river in the Tyrol, where conditions are also suitable for development in several stages, and construction of the Gerlos power plant was initiated. Work was started only on the lower stage which was not finished until after the war (1948). The capacity of the plant, which comprises four generating units each of 15,400 kW, amounts to 61,600 kW. At present the Tauernkraftwerke A.G. is studying the possibilities for the full development of the Gerlos river on which in addition, as shown in Figs. 7 and 9, a medium and an upper stage and an annual storage reservoir of 51,000 acre-ft. could be constructed whereby a head of about 2,600 ft. could be utilised. Project work is advancing.

The gradually progressing development of Austria's hydro-power resources induces the companies responsible to ascertain the developable resources in their respective areas and to elaborate projects ready for construction. It has often been asserted that Austria's developable hydro-power resources amount to 40 to 45 billion (10^9) kWh. This is merely a pro-

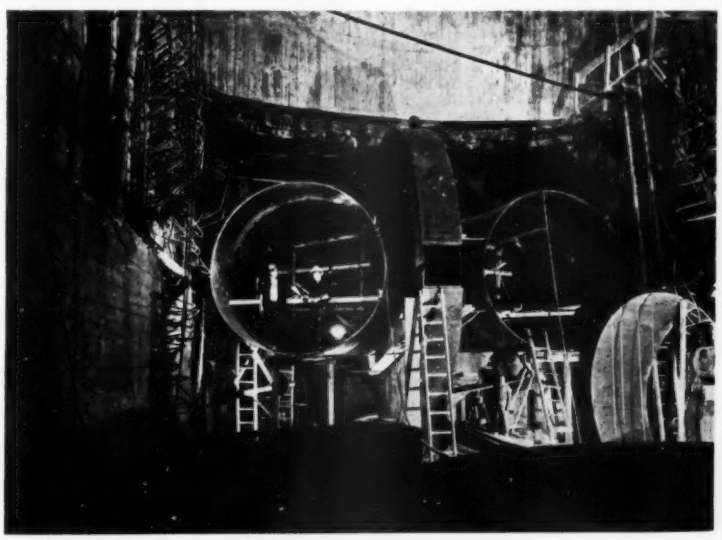

Fig. 6. Y pipe at entrance to lower valve chamber

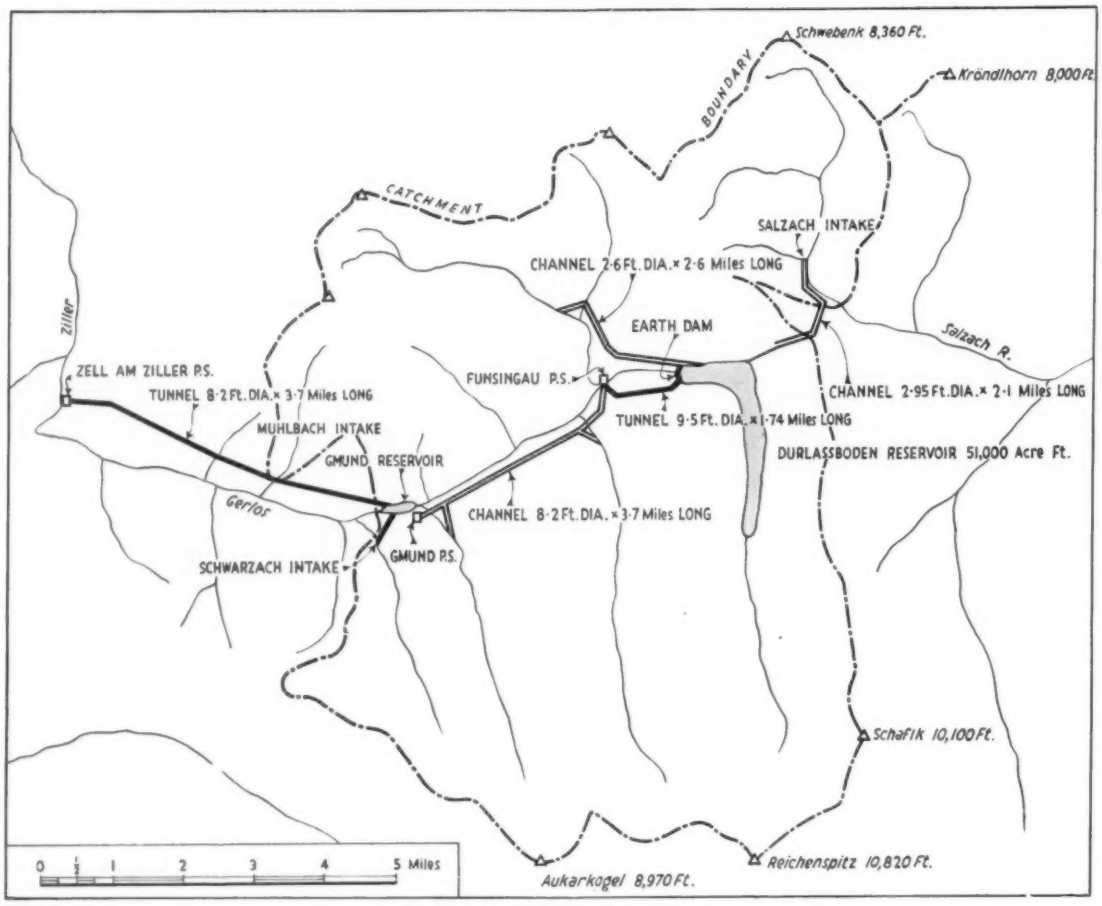

Fig. 7. Map of Gerlos project

Fig. 8. Compacting the earth dam for the Brandstatt storage reservoir

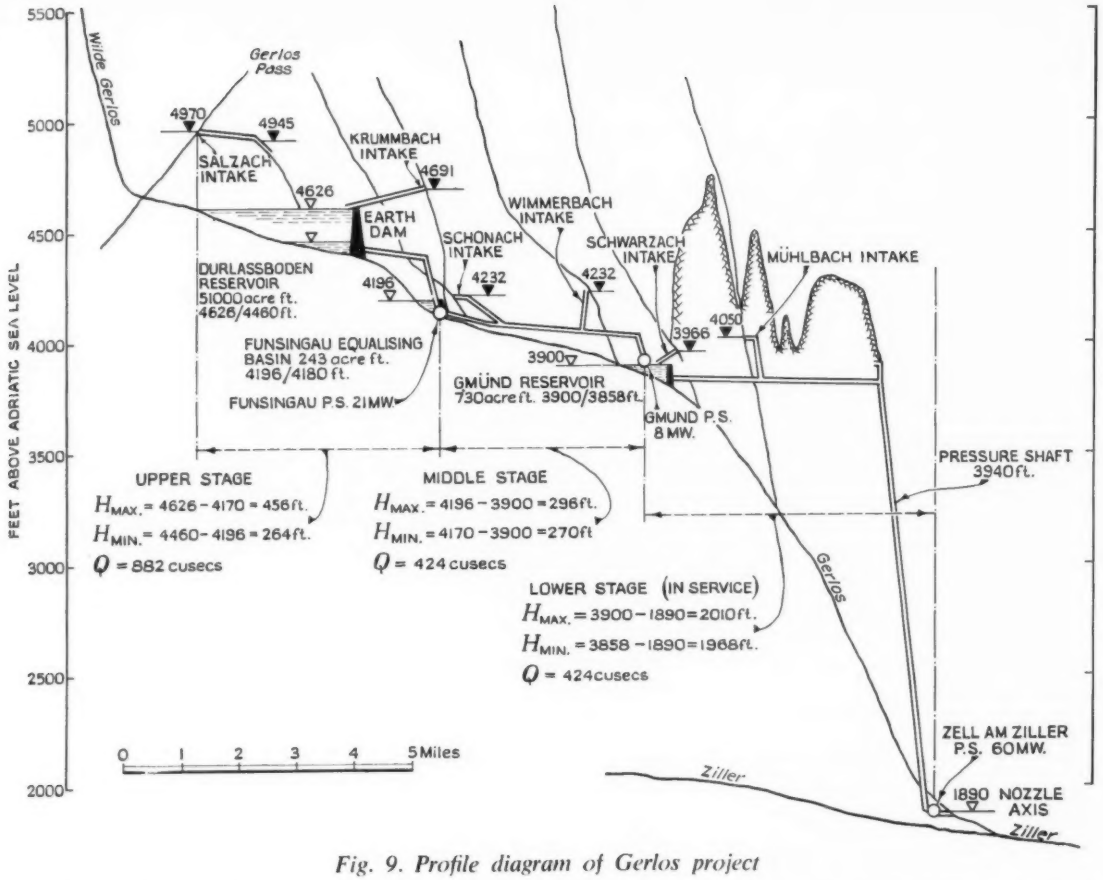

Fig. 9. Profile diagram of Gerlos project

visional estimate and has not been established on the basis of elaborated projects for the entire hydro-power resources. It would serve no purpose now to elaborate projects ready for construction which would not be realised in the foreseeable future. Even the very promising projects of the international study company "Interalpen"* concerning the development of the Ötz river, the Bregenzer Ache and of the projects in Eastern Tyrol have not yet been initiated although their realisation lies in the interest of several European countries. There is no doubt, however, that from Austria's hydro-power resources more than 40 to 45 billion kWh could economically be produced.

The most economical way for covering Europe's energy shortage will be the international development of hydro-power resources. The above statements refer only to a few possibilities existing in Austria for the generation of large blocks of energy, and particularly of winter energy from hydro-power in an economically profitable manner.

* *See* WATER POWER, February 1953, page 71.

New Protective Coating for Steel and Concrete. A folder issued by Wailes Dove Bitumastic Limited (Technical Leaflet No. 20) describes a new protective coating which this firm has developed for metal and concrete surfaces. It is said to combine the waterproofing properties of coal-tar-pitch with the resistance to chemical attack and corrosion of epoxy resins. The material is claimed to have excellent adhesion to both metal and concrete surfaces and to be able to withstand exposure to acids, alkalis, oils, fats and many other corrosive chemicals. At the same time, the coating, which is called "Epimastic," has excellent resistance to abrasion and other forms of mechanical wear, or shock. It can be applied either by brush or spray equipment to almost all types of industrial equipment where surface protection is desired, and retains its properties over long periods of time. The makers specially recommend this product for protecting penstocks, surge tanks and tunnel linings.

Bottom Discharge Valves for Dams. In our article under this title published in the July issue there is a typographical error five lines down from the top of the right-hand column on page 257; for 63%, 93% should be substituted. Also, in the same column, two lines down from Fig. 9 the equation should read: $c = \alpha\sqrt{2gH}$, and four lines down the division sign should be replaced by a plus sign. On page 258 the division sign in line four should also be replaced by a plus sign and in line 18 the equation should read $\sigma A = -0{\cdot}354$, the minus sign having been omitted.

The Correlation of Nuclear, Thermal and Pumped-Storage Capacity

Price estimates for energy produced by two or more combined sources of power are discussed in this final section

By DR. CHARLES JAEGER

PART THREE

THE estimate of production costs for electrical energy is a major problem which will keep busy a fully specialised department of any large generating concern. Many recent publications and text books deal with this subject and lectures are delivered on the same syllabus at some universities by specialised teachers, for example at Graz in Austria. The production costs will depend to some extent on the installed capacity N, and to some extent on the energy E produced and sold, and on the load factor θ of the power station. In all the cases linear equations of the type (19) or (20) can be set up, where some of the coefficients will depend on θ. For steam power stations the following formula is often used (where $\theta = \theta_{st}$)*:

$$k_s = \frac{a_s r_s p_s}{\theta_{st} T \eta_s} + \frac{a_t p_t}{\theta_{st} T} + \frac{wb}{\eta_t} \qquad \ldots(21)$$

For pumped storage a similar formula has been published.

$$k_p = \frac{a_p r_p p_p}{\theta_p T \eta_p} + \frac{a_t p_t}{\theta_p T} + \frac{w_2 b}{\eta_p \eta_t} \qquad \ldots(22)$$

Both formulae are obviously of the type (19). In these formulae

a_s = capital charge of steam station in £ per kW
a_t = capital charge of transmission lines in £ per kW
a_p = capital charge of pumped storage in £ per kW
r_s = reserve factor for steam (ratio of rated capacity to real maximum capacity) $r_s \cong 1{\cdot}17$
r_p = reserve factor for pumped storage, $r_p \cong 1{\cdot}05$
p_s = yearly dividend of the capital charge for steam
p_p = yearly dividend of the capital charge for pumped storage
p_t = yearly dividend of the capital charge for transmission

These values p will depend mainly on the rate of interest and the rate of amortisation. As the formula is written, p will also include the operating expenses, unless they are accounted for separately in an additional fourth term similar to the third term and depending mainly on the energy E produced or sold.
θ_{st} is the load factor for steam
θ_p is the load factor for pumped storage
$T = 8760$ hours a year
η are efficiency factors, η_t referring to transmission efficiency and η_p to pump efficiency
w is the conversion factor of coal in lb. to kWh
w_2 is the marginal price for production of "additional" steam power
b the price of coal per lb.

Equations of this type have been developed years ago by Mr. L. Musil, and B. Jansen and K. H. Haager have used this method to analyse the cost per kWh in a steam station and in a combined system including steam and pumped storage.

It will be shown that this method can be further developed and that it applies equally well to combined nuclear and pumped energy, combined water power and pumped energy, and to more intricate cases where steam power and water power are produced in parallel with stored energy or pumped energy. The procedure is either to calculate the constants a_s, a_t, a_p etc., and use the equations direct or to write down actual figures to be introduced in the balance sheets.

The Economics of Nuclear Power combined with Pumped Storage

Data on nuclear power costs

Data on the economics of large atomic stations were published in Great Britain in 1957. The total sum involved in tenders on large stations ranging from 300 MW to 500 MW has also been made public. It is estimated that atomic power will cost about £100 to £145 per kW installed.

Detailed figures have been published by Mr. J. A. Jukes,† Economic Adviser to the U.K.A.E.A., Sir Christopher Hinton and Miss Mary Golding.‡

Table IV, by Mr. Jukes and Sir Christopher Hinton, will form a basis to our own investigations. The figures given by Mr. Jukes are based on a 0·70 load factor. The source of these figures can readily be checked.

Let us assume a 300 MW atomic station costing £130 per kW. installed, or £39,000,000. Assuming dividends and amortisation total 8%, the yearly capital charges would be £3,120,000. The 8% is based on a 4½% rate of interest. A load factor of 0·70 corresponds to 6130 working hours at full load;

* See B. Jansen and K. H. Haager: "Die energiewirtschaftliche Bedeutung der Pumpspeicherwerke": Regensburg 1957.

† See Atomic Review on Paper by Mr. J. A. Jukes, *Engineering*, London, June 14th 1957.

‡ Mary S. Golding, "The Economics of Atomic Energy," Butterworth, London, 1957.

TABLE IV
APPROXIMATE COST OF ELECTRICITY FROM NUCLEAR STATION AS ESTIMATED BY UNITED KINGDOM ELECTRICITY AUTHORITY (PRICES IN PENCE PER kWH SENT OUT)

	According to J. A. Jukes	According to Sir Christopher Hinton	
		1960	1970
Amortisation: capital charge 8%	0·37 to 0·40	0·37	0·30
Interest on initial fuel charge 5%	0·05 to 0·06	0·06	0·04
Fuel replacement cost (gross)	0·22 to 0·25	0·24	0·13
Operating expenses (about)	0·05	0·06	0·06
Total gross cost ..	0·69 to 0·76	0·73	0·52
Plutonium credit (about)	0·07	0·07	0·05
Total net cost (say) ..	0·6 to 0·7	0·66	0·47

(0·7×8760 = 6130 hours) or a yearly output of 300,000×6130 = 1,839,000,000 kWh
The cost per kWh is:

$$\frac{39{,}000{,}000\times 8\times 240}{100\times 1{,}839{,}000{,}000} = 0{\cdot}406\text{d./kWh}$$

for capital charges only, which compares with the figures given in the table.

Starting from the figures given by Mr. Jukes we get Table V for nuclear power.

TABLE V. COST OF NUCLEAR POWER

	d. per kWh	£ per annum
Capital charges (8% basis) ..	0·406	3,120,000
Interest on initial fuel	0·054	415,000
Fuel replacement cost ..	0·250	1,920,000
Total gross cost	0·710	5,455,000
Operating expenses	0·05	385,000
Total	0·76	5,840,000
Deduct: Plutonium credit about	0·07	546,000
Total	0·69	5,294,000

DATA ON PUMPED STORAGE.

From German sources,* it is estimated that pumped-storage capacity cost in £ per kW installed is
For a head of 100 m DM 800 to 1000 or £68 to £86.
For a head of 500 m DM 400 to 530 or £34 to £47.

From British sources† the following figures have been published (1956 prices):—

Ffestiniog. 300 MW. Gross head = 1,089 to 981 ft. (324 to 298 m). Cost per kW is £40, or if transmission costs are included, £47·5.

Balmaha. 360 MW. Gross head 690 to 640 ft. (210 to 195m). Cost £41 per kW, transmission included.

Loch Sloy Project (about 2,000 MW). Cost £40 per kW installed.

Cruachan. Cost £39 per kW.

It may thus be assumed that £50 per kW installed capacity is a fair estimate, based on price levels of the year 1956, similar to those on which the figures of Mr. Jukes are based.

Case of the Nuclear Base-Load Station Working at Full Capacity ($\theta_B = 1$)

Let us first consider the case of a nuclear base-load station working always at full capacity ($\theta_B = 1$). According to figures developed in the previous section a 300 MW atomic station working at full load ($\theta_B = 1$) and directly connected to a convenient pumping station to satisfy a system load characterised by $\theta = 0{\cdot}7$ requires about

$$300\times\frac{0{\cdot}275}{0{\cdot}725} = 300\times 0{\cdot}379 = 137{\cdot}7 \quad \text{or} \quad 115\ \text{MW}$$

installed generating capacity at the pumping station. The total installed capacity would be 300+115 = 415 MW. Assuming a load factor $\theta = 0{\cdot}7$ this capacity would produce in (0·7×8760)=6132 hours:—

415×0·7×8,760 = 2,550,000,000 kWh a year

The increase in energy generation is therefore 2,550,000,000−1,839,000,000 = 711,000,000 kWh a year, or as expected, about 771/1839 = 38%.

As already indicated in the previous section, this calculation is based on an efficiency factor $\eta = 0{\cdot}70$ which does not account for long transmission lines. If long transmission lines are included an additional correction will need to be made.

The energy generated by the pumping station would be 415,000×8,760×0,049 = 178,000,000 kWh. This is small in comparison with the 711,000,000 kWh increase in the energy generated per annum. The energy losses are $(1-\eta)A_2/A_1$ times this amount, or 77,000,000 kWh. A most important point to be discussed here is the cost of this additional energy. It is expected that it will not cost more to run a nuclear station all the night long with constant power output than to slow it down. The only losses are those due to the efficiency factor of converting the pumped energy into generated energy. These losses are already accounted for in the general balance of power and energy generation.

If the two power stations, the nuclear base-load and the peak-load station are combined as a unit, any amount charged to either station for energy produced in the other, appears on both sides of the balance sheet and does not influence the final cost and price estimate.

The additional yearly expenses really incurred are as follows:—

Capital cost for a 114,000 kW pumping station at £50 per kW or £5,700,000. As amortisation of a hydro power station is far lower than for a nuclear station, a 7% basis for interest and amortisement is assumed here. It follows then that the capital charges (7% basis) are £400,000 per year. The total yearly expenditure for capital charges for both stations including initial nuclear fuel and fuel replacement is therefore:—

For the nuclear station	...	£5,455,000
For the pumping station	...	£400,000
Total		£5,855,000

The operating expenses are 0·05d. per kWh generated including the nuclear base load, the pumped energy and the energy losses; this makes 2,550,000,000 +77,000,000 = 2,627,000,000 kWh a year at 0·05d. or £545,000 a year.

* B. Jansen and K. H. Haager, op.cit.

† A. A. Fulton, T. G. N. Haldane and N. W. Mountain, "The Practical application and Economics of Pumped Storage in Great Britain." World Power Conference, Vienna 1945.

The total expenses per annum are therefore

Capital charges	£5,855,000
Operating expenses	£545,000
Total expenses	£6,400,000

Assuming an unchanged credit for plutonium of £546,000 then the toal expenses would be about £5,850,000 a year, or $(5,850,000 \times 240)/2,550,000,000 = 0{\cdot}55$d. per kWh instead of 0·69d. per kWh for nuclear energy alone. The gain is 0·14d. per kWh or $0{\cdot}14/0{\cdot}69 = 20\%$ for unit prices for the kWh generated energy.

Nuclear Base-Load Station not working at full capacity

The cost estimate can be extended to cases where the base-load station (nuclear station or other) does not always work at full capacity ($\theta_B < 1$).

For $\theta = 0{\cdot}75$ and $\theta_B = 0{\cdot}82$ it was found that $N_B = 0{\cdot}915$, and $N_1^* = 1 - N_B = 0{\cdot}085$ so that the installed capacity of the pumped-storage scheme should be at least 0·093 or 9·3% of the total capacity.

Similarly, with $\theta = 0{\cdot}70$ and $\theta_B = 0{\cdot}82$ it will be found that $N_B = 0{\cdot}878$, $N_1^* = 1 - N_B = 0{\cdot}122$, and the pumped-storage capacity should be (at least) 0·139 or 13·9%. Assuming again the nuclear station to be a 300 MW station, the capacity of the pumped storage should be for $\theta = 0{\cdot}7$d.

$$300 \times 0{\cdot}139 = 41{\cdot}75 \text{ MW}$$

or about 42 MW.

The total installed capacity would be 342 MW, which, working at a $\theta = 0{\cdot}70$ load factor, would produce ($\eta = 0{\cdot}70$)

$342,000 \times 0{\cdot}7 \times 8,760 = 2,095,000,000$ kWh per annum

The gain in energy compared with nuclear power alone would be

$2,095,000,000 - 1,839,000,000 = 256,000,000$ kWh

or, as expected, about 13·9% in excess of what the nuclear station would produce, if working alone with $\theta = 0{\cdot}70$.

The yearly capital charges for 42,000 kW installed capacity in the pumping station would be $42,000 \times 50 \times 0{\cdot}07 =$ £148,000 per year. The energy losses correspond to about $342,000 \times 8,760 \times 0{\cdot}0024 = 7,100,000$ kWh a year with $\Delta A = 0{\cdot}0024$.

With these figures, the annual capital charges are now:—

For the nuclear station	£5,455,000
For the pumping station	£148,000
Total	£5,603,000

The operating expenses are 0·05d. per kWh generated, calculated for $2,095,000,000 + 7,100,000 = 2,102,000,000$ kWh or £437,000 a year.

The total expenses per annum are now:—

Capital charges	£5,603,000
Operating expenses	£437,000
Total expenses	£6,040,000

Assuming a credit for plutonium of £546,000 the final yearly expense account shows £5,494,000 or $(5,494,000 \times 240)/2,095,000,000 = 0{\cdot}63$d. per kWh instead of 0·69d. per kWh for a nuclear station working alone. For $\theta_B = 0{\cdot}82$ the gain is now 0·06d. per kWh or $0{\cdot}06/0{\cdot}64 = 8{\cdot}7\%$ only, compared with 20% for $\theta_B = 1$.

This shows that the base-load station must work at the highest possible load factor ($\theta_B \cong 1$) to get full benefit from the pumping capacity which has to be designed accordingly.

Combined Run-of-river Hydro Power and Pumped Storage (Figs. 22, 23, 24, 26)

The same method allows the solution of another quite different but vital problem. Suppose the main power source to be a run-of-river station located at about 500 miles (800 km) from the main centre of consumption. The installed power is $N_0 = 500$ MW. In order to get the best load factor for this distant power, a pumped storage is built near the centre of consumption. The efficiency of the pumped storage is $\eta = 0{\cdot}7$ but the line losses over a distance of 500 miles may represent another 10% loss in efficiency, thus reducing the overall efficiency of the pumping process to about $\eta = 0{\cdot}6$.

Former calculations show that for a system load curve characterised by $\theta_s = 0{\cdot}65$, $\theta_0 = 0{\cdot}42$ the following relative values where found:—

$$N_B = 0{\cdot}68, \quad N_1^* = 0{\cdot}32$$
$$A_2 = 0{\cdot}086, \quad A_1 = 0{\cdot}092, \quad \Delta A = 0{\cdot}034$$
$$\theta_p^* = A_1/N_1^* = 0{\cdot}14 \text{ (See Fig. 22)}$$

The corresponding absolute values are $N_B = 500$ MW, $N_1 = 238$ MW and $M = 735$ MW. Suppose the capital charge a_w of the run-of-river station is based on a unit price of £125 per kW, whereas the pumped storage (assuming pure pumped storage) a_p is estimated at £50 per kW, or 40% of the cost of hydro-power. For both stations, the overall yearly dividend of the capital charges (including operating expenses) is taken as $p_w = p_p = 10\%$. The capital cost of the transmission lines is estimated at £20,000 per mile or £10,000,000 for 500 miles.†

When the water power station is working alone, it would produce a yearly output of (Fig. 22):—

$$Ew_1 = \theta_s N_0 T$$
$$= 0{\cdot}65 \times 500,000 \times 8,760 = 2,845 \times 10^6 \text{ kWh}$$

Owing to 10% transmission losses, this figure is reduced to $2,560 \times 10^6$ kWh.

The capital cost involved is:

For the hydro-power station	
£500,000 × 125 =	£62·5 × 10⁶
For the transmission lines	£10·0 × 10⁶
Total	£72·5 × 10⁶

or $a_w + a_t =$ £145 per kW.

Assuming $p = 10\%$, the yearly capital charge would be £7·25 × 10⁶ or,

$(6{\cdot}25 \times 10^6 \times 240)/(2,560 \times 10^6)$

= 0·586d. per kWh for power production
0·094d. per kWh for power transmission lines
and 0·680d. per kWh for power at the consumption centre.

When the two stations are working together (Fig. 22) the total energy produced every year is

$$0{\cdot}65 \times 735,000 \times 8,760 = 4,185,000,000 \text{ kWh}$$

Of this total the hydro-power has produced

$$500,000 \times 8,760 = 4,380,000,000 \text{ kWh}$$

which, owing to the 10% transmission losses is reduced to 3,942,000,000 kWh at the centre of consumption. The pumping losses $\Delta A = 0{\cdot}03$ have already been calculated with $\eta = 0{\cdot}6$ including transmission losses. The corrected losses due to pumping only are ($\Delta A' = 0{\cdot}03 \times 0{\cdot}6/0{\cdot}7$)

† See J. Guthrie Brown and P. J. Ryle "Hydro-Electric Engineering Practice," Volume II, Chapter XV. p. 594.

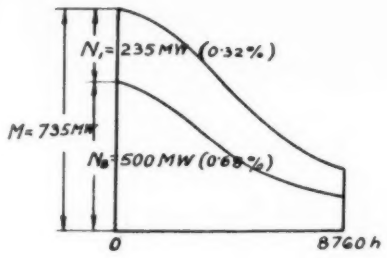

FIG. 22.

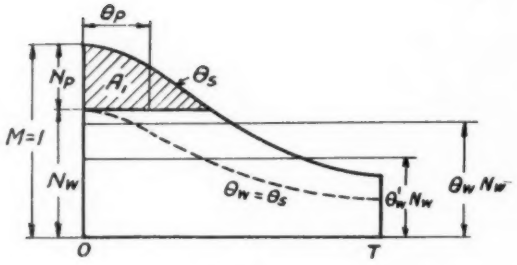

FIG. 23.

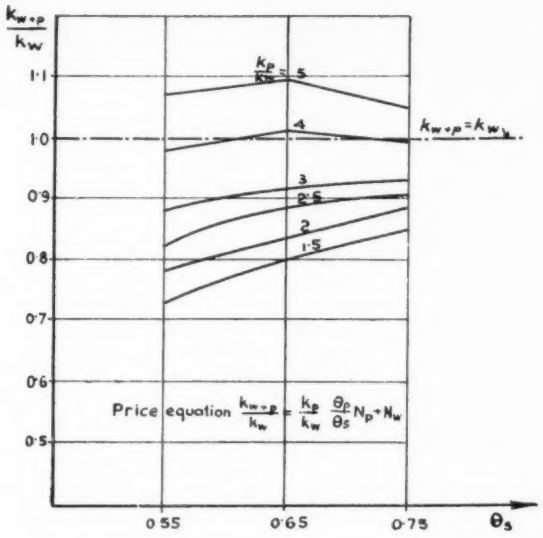

FIG. 24.

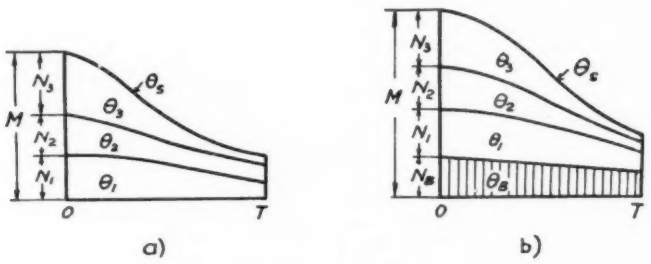

FIG. 25.

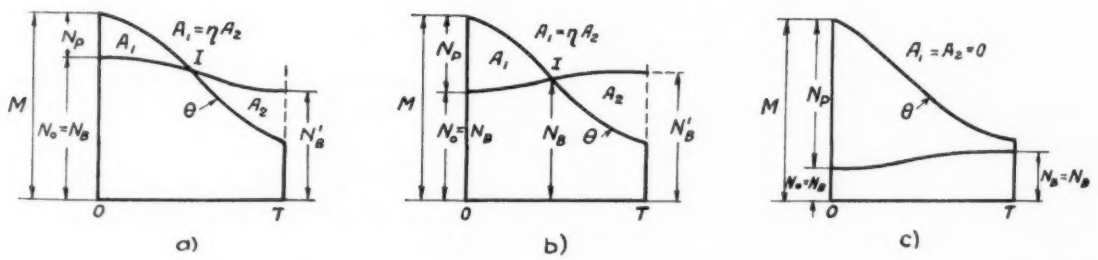

FIG. 26.

$$0{\cdot}03 \times \frac{0{\cdot}6}{0{\cdot}7} \times 735{,}000 \times 8{,}760 = 165{,}000{,}000 \text{ kWh}$$

Total $W+P$ = 3,770,000,000 kWh

This, as is to be expected, is 90% of 4,185,000,000 kWh. Of this total the pumped energy represents

$0{\cdot}052 \times 735{,}000 \times 8{,}760$ or $P = 335{,}000{,}000$ kWh

and the remaining generated hydro-power amounts to

$W = 3{,}435{,}000{,}000$ kWh

The cost of the hydro generated power unit available for sale, transmission loss included, is now:—

$$k'_w = \frac{7{\cdot}25 \times 10^6 \times 240}{3{,}435 \times 10^6} = 0{\cdot}5\text{d per kWh}$$

The capital cost of the pumped storage is

$£50 \times 235{,}000 = £11{,}750{,}000$

We assume the pumped storage to be near the centre of consumption so there are no transmission costs and a_p = £50 per kW (if there is a substantial length of transmission line, say, 100 miles, then an additional $235/500 \times 100/500 \times 10^7$ = £94,000 would have to be added on or a_{pt} = £4 per kW).

The yearly capital charge ($p_p = 10\%$) is £1,175,000.

The cost of 1 kWh generated at the pumping station is then

$$k_p = \frac{1{,}175{,}000 \times 240}{335 \times 10^6} = 0{\cdot}84\text{d. per kWh.}$$

The price for energy produced by the combined stations and available at the centre of consumption will be given by

$$k_{W+P} = \frac{k_p P + k'_w W'}{P + W'} \qquad \ldots(23)$$

or

$$k_{W+P} = \frac{3{,}435 \times 10^6 \times 0{\cdot}5 + 335 \times 10^6 \times 0{\cdot}84}{3{,}770 \times 10^6} = 0{\cdot}523$$

The economy per kWh would be $0{\cdot}680 - 0{\cdot}523 = 0{\cdot}15$d. or $0{\cdot}15/0{\cdot}680 = 22\%$. It is desirable to know how these figures may change if the ratios k_p/k_W and θ_p/θ_s vary, these being obviously the more important parameters of the problem. This more general approach to the problem can be introduced as follows. According to Fig. 23 and to formula (1), formula (23) (see Fig. 23) can be written ($M = 1$, $T = 1$)

$$\frac{k_{W+P}}{k_w} = \frac{k_p N_p \theta_p + k'_w(\theta_s - N_p\theta_p)}{\theta_s k_w}$$

where $A = MT\theta_s = \theta_s$

$A_1 = N_p\theta_p$

$\theta'_w = (\theta_s - N_p\theta_p)/N_w$

$A - A_1 = \theta_s - N_p\theta_p = N_w\theta'_w$

$\theta_w = \theta_s$ (See Fig. 23)

In addition we have ($p_w = p_p = p_t$):

$$k_w = \frac{(a_w + a_t)p_w}{\theta_w}$$

and

$$k'_w = \frac{(a_w + a_t)p_w}{\theta'_w}$$

where k_w refers to the hydro-power station working alone and producing $W = N_w\theta_w = N_w\theta_s$ units over the period T and k'_w refers to the hydro-power station working in combination with pumped storage and producing $W' = \theta_s - N_p\theta_p$ units. Therefore:

$$\frac{k'_w}{k_w} = \frac{(a_w + a_p)p_w}{\theta'_w} \frac{\theta_w}{(a_w + a_p)p_w} = \frac{\theta_s N_w}{\theta_s - N_p\theta_p}$$

and finally

$$\frac{k_{W+d}}{k_w} = \frac{k_p\theta_p}{k_w\theta_s} N_p + N_w$$

Power produced by a combined system of water power and pumped energy is cheaper than energy produced by water alone provided that $k_{W+P}/k_w < 1$. With $N_w + N_p = M = 1$, the final condition is

$$\frac{k_p}{k_w}\frac{\theta_p}{\theta_s} \leqslant 1 \quad \text{or} \quad \frac{kp}{k_w} \leqslant \frac{\theta_s}{\theta_p}$$

This condition is absolutely general and depends neither on the type of duration curve assumed nor on the proportion of excess water power being used for production of pumped storage.

In the case previously discussed

$$\frac{k_{W+P}}{k_w} = 0{\cdot}68 + 0{\cdot}32\frac{0{\cdot}14}{0{\cdot}65} \times \frac{0{\cdot}84}{0{\cdot}68} = 0{\cdot}77$$

or about the same as obtained by direct computation. (The small difference is due to the estimated transmission losses.) In addition:

$$k_p\theta_p/k_w\theta_s = 0{\cdot}308$$

and

$$k_p = 1{\cdot}43\, k_w.$$

The identity of prices $k_w = k_{W+P}$ would be obtained if

$$k_p = (0{\cdot}65/0{\cdot}14)k_w = 4{\cdot}65\, k_w$$

or

$$k_p = 4{\cdot}65 \times 0{\cdot}68 = 3{\cdot}16\text{d.}$$

The example assumed full use of the water. If this is not so then θ_p would be smaller than 0·14 and k_p could be even larger than 4·65 before equality of the prices $k_w = k_{w+p}$ would be reached. This shows the wide margin for the price k_p. Fig. 24 has been established for $\eta = 0{\cdot}70$ (transmission length $L = 0$) and varying values of θ_s and k_p/k_w. Another, possibly simpler approach would be to trace the duration curve shown in Figs. 22 and 23, not for the generating station located at great distance L, but for the receiving end near the centre of the consumption. This discussion refers explicitly to a run-of-river station. Alternative cases for running the base-load station differently are shown in Figs. 26a to 26c. Where gravity-water storage and pumped storage are being compared, marginal prices and costs for a pumped storage will have to be compared with the cost of an enlarged hydro-power station. Such an enquiry depends on too many technical and economic parameters which can hardly be summarised for a general discussion. In addition, generation of off-peak energy by a run-of-river station will usually have to be considered in relation to pumping water in the storage and thus combining not only two but three stations in one system.

A most promising line will be the extension of conventional storage schemes by the inclusion of pumped storage, in order to develop mixed-storage schemes. This line of thought has been analysed in a previous paper on pumped storage.*

The importance of combining pumped storage with conventional gravity storage is shown by the fact that even in countries with abundant water power, there is not enough power stored in winter to balance the summer (run-of-river) power. When nuclear power is developed, pumped storage will become unavoidable in order to balance the duration curves even in such systems which, for the time being, rely mainly on conventional hydro power.

Combined Steam Power and Pumped Storage

This problem has been dealt with extensively by B. Jansen and K. H. Haager,† who compare a system fed solely by steam and the alternative of combined generation by steam and pumped storage. For the sake of comparison both alternatives are supposed to be new stations and costs are referred to a same price basis (1956).

Equations (21) and (22) are used. The main difference—as compared with the previous two subsections of this article—is that the terms wb/η_t and $w_2b/\eta_p\eta_t$ get now their full weight in the equation of prices.

Their estimates are based on the following data:—

$\theta_s = 0{\cdot}513$ (4,500 hours)

$\theta_p = 0{\cdot}137$ (1,200 hours)

$N_B = N_{st} = 0{\cdot}75$ of the combined capacity in case of the second alternative, and

$N_p = 0{\cdot}25$ ($M = N_B + N_p = 1$).

(The actual capacity of the pumping station is 27,000 kW.)

They show that the yearly energy produced by steam S represents 93·3 of the total energy E_{tot} =

* C. H. Jaeger, "The Economics of Pumped Storage." WATER POWER, February 1957, p. 54, and March 1957, p. 104.

† See B. Jansen and K. H. Haager, *op.cit.* and also J. Guthrie Brown and G. K. Hunter "Hydro Electric Engineering Practice" Vol. III.

$S+P$, and that $P = 6{\cdot}7\%$ is pumped energy. These figures line up well with what has been found above for other cases. The capital charges are calculated on a basis of 19% for steam, 12·5% for pumping and 12% for transmission.

If steam alone is used, the cost of 1 kWh steam generated is 5·09 Pfennig or 1·04d. Owing to the higher rate of utilisation of the steam plant when connected to a pumping plant, the generating cost for 1 kWh by steam drops in the second alternative to about 4·5 Pfennig or 0·925d. per kWh. The cost of generating 1 kWh at the pumping station is 10·2 Pfennig or 2·1d. per kWh and the combined price is obtained with formula (23) and amounts to 4·06 Pfennig or 0·992d., so that an economy of 4·5% is achieved.

The economy achieved with such a combination of generating stations is still substantial but less than for a combination of pumped storage with nuclear power or with water power (run-of-river station) because of the additional weight of coal which has to be burnt for producing the energy required for pumping.

Comparison with figures published in the U.S.A. is of great interest. According to Mr. Edward S. Loane, pumped storage in the U.S.A. would be economic if the installed kW of pumped storage were costing less than $165. He estimates the cost for a number of projects he has examined at $125 to $150 which compares well with costs in Great Britain.

As the cost of steam capacity is $150 per kW, the ratio of 1 kW pumping capacity to 1 kW steam capacity would vary between 0·835 and 1, with 1·1 as permissible limit. Fixed charges are estimated at 12·5% for steam and 12% for pumped storage.

In his essay, Mr. George R. Rich reaches opposite conclusions. In the case he analyses steam base load plus pumped-storage peak load is dearer by about 5·7% than steam alone. It is well worth while to analyse his figures and to compare them with the figures published by others. This is done in Table VI.

Analysis of the figures of Mr. Rich shows that American taxation is detrimental to the steam-pumped-storage combination. If taxes are ignored the combination would be only 2·2% more expensive than steam alone.

The difference between the estimates of Mr. Rich and M. Jansen boils then down to differences in estimating η and the percentage of capital charges and the main turnover charges.

TABLE VI

	Rich	Loane	Jansen
1 kW steam capacity ..	$180	$150	DM 500 ($120)
1 kW pumped-storage capacity	$250	$125–150	DM 700 ($168)
Ratio pump to steam ..	1·39	0·82–1·0	1·4
% of fixed charge for steam	6·9*	12·5†	19
% of fixed charge for pumps	6·9*	12·0†	12·5
Price of coal, per ton ($)	$7·75	—	$14
or cents per kWh ..	c0·275	—	c0·457
Pump-turbine cycle efficiency η	0·635		0·71
Load factor	0·6		0·513

* Includes return and depreciation only. If fixed costs included this figure would be 13·5%, comparing with Loane's 12·5% and 12%.

† Includes interest, return, depreciation, all taxes and insurances. Running and maintenance costs excluded.

This analysis shows that a combination of steam and pumped storage is less inviting than the other combinations which we have considered in the previous sub-sections. Conditions are also more complicated and the cost of coal is an unfavourable factor. No simple diagram similar to Fig. 24 could be traced for steam.

In his comments Mr. Rich points out that more favourable conditions for the pumping station would reverse his findings. Pumping may be an economic solution when the whole system (including old steam stations) and water power is being considered.

In another section of his essay Mr. Rich then finds that a combination of hydro power and pumping capacity (example: American Niagara Falls Scheme) is highly economical, thus supporting the views expressed in the previous sub-section. This is the more interesting as the cost of the American Niagara Falls pumping station is high.

Price Problems for a System Divided in Three or More Areas.

When a system is divided into three or more areas the mathematical analysis becomes more involved and in many cases there are several possible solutions. It will often be a matter of judgment to select the more profitable one. Detailed calculations may become so involved that computing machines may be required.

The direct mathematical analysis may nevertheless give useful answers to some fundamental problems.

(*a*) *Remarks on prices of Electrciity Generation.* The price of 1 kWh of generated electricity k_t can usually be split up as follows:—

$$k_t = \frac{A_t}{\theta_t} + B_t \qquad \ldots(24)$$

when A_t is the yearly capital charge for installed kW multiplied by the convenient conversion factor as in equation (21). To get the correct effect of this yearly capital charge on the price of the kWh, A_t must be divided by the corresponding load factor θ_t. If the electricity is steam generated, A_t will include the cost of banking energy. B_t includes all the costs which are directly proportional to the number of kWh produced (as the price of coal for production of steam power).

Any change in the structure of the system and any shedding of load from one type of generation to another may influence the generation of other stations and modify either A_t or B_t and the final effect of this load shedding on the whole system will have to be judged accordingly.

A reduction in the cost of coal (B_t) may be offset by a change occurring in the load factor θ_t. Usually the cost of analysis cannot be restricted to what happens on one station only.

(*b*) *Fundamental Problem: Introduction of a new source of energy in an existing system. "Condition of no change in prices".* A system is characterised by the system load factor θ_s and the total capacity M. It is split up into partial energy areas, so that:

$$M\theta_s = N_1\theta_1 + N_2\theta_2 + N_3\theta_3 + \ldots \qquad \ldots(25)$$

A new station with capacity N_B is introduced in the system, the condition being that there should be no change in the prices k_t of the partial energy areas. Therefore, the N_t and θ_t on which A_t and k_t (equation (24)) depend must remain constant. Let θ_B be the

load factor of the new energy area. Then, we should have:

$$M'\theta_s = (M+N_B)\theta_s$$
$$= N_1\theta_1+N_2\theta_2+N_3\theta_3+ \ldots +N_B\theta_B \quad \ldots(26)$$

By simple subtraction it follows that

$$N_B\theta_s = N_B\theta_B$$

and $$\theta_B = \theta_s \quad \ldots(27)$$

If conditions and prices for the different energy areas or components of the system have not to be altered, the load factor of the new source of energy θ_B should be equal to the system load factor θ_s.

Suppose a system, with load factor θ_s, which is mainly fed by steam stations of different age and efficiency. The newest most efficient steam stations N_1 or N_2 will have relatively high load factors θ_1, θ_2, so that $\theta_1 > \theta_2 > \theta_s$. If a new source of energy N_B (say nuclear energy) is added to the system, and it is found desirable that no change should occur in the price structure of the existing stations, then the desirable value θ_B should be $\theta_B = \theta_s$, a factor which may be much lower than θ_1 or θ_2.

We have already investigated in the previous sections the relation that should exist between N_B, θ_B, M and θ_s to achieve such a result and found that pumped storage is often the best possible answer to the technical problems involved.

(*c*) *Case where the new source of energy should allow a change of some of the system components.* The load factor θ_t of the system component N_t is supposed to be altered, say that the new load factor θ'_t of this component should be $\theta'_t \neq \theta_t$. Then $\theta'_t = \theta_t+\Delta\theta_t$ and:

$$M\theta_s = N_1\theta_1+N_2\theta_2+ \ldots +N_1\theta_1 \ldots$$
$$(M+N_B)\theta_s = N_1\theta_1+N_2\theta_2+ \ldots$$
$$+N_t(\theta_t+\Delta\theta_t)+ \ldots +N_B\theta_B$$
$$N_B\theta_s = N_t\Delta\theta_t+N_B\theta_B$$

and $$\theta_B = \theta_s-\frac{N_t}{N_B}\Delta\theta_t$$

This equation can obviously be extended to several components like i, $i+1$, $i+2$ . . . and so on.

It is remarkable that a direct relation can be set up between θ_B and θ_s, $\Delta\theta_t$ disregarding all the other components of the system. If it is desirable to improve the load factor of one (or more) components, the new component $N_B\theta_B$ can readily be estimated with equation (28) to get the required result.

(*d*) *Price equation.* The price equation (24) can be generalised. Let E_1, E_2, E_3 . . . E_p be the quantities of energy in kWh generated at the price k_1, k_2, k_3 . . . k_p, then the price of the unit energy produced by the system will be given by

$$(E_1+E_2+E_3+ \ldots +E_n)k = \sum_1^n E_tk_t = \sum_1^n \frac{A_t}{\theta_t}+\sum_1^n B_t \quad \ldots(29)$$

If a new price component E_Bk_B is introduced and if the components E_nk_n, $E_{n-1}k_{n-1}$ have to be modified owing to modified load factors θ_n, θ_{n-1}, then the new average price k' will be:

$$(E_1+E_2+ \ldots +E_{n-1}+E_n+E_B)k' =$$
$$\sum_1^{n-2}\left(\frac{A_t}{\theta_t}\right)+\frac{A_{n-1}}{\theta'_{n-1}}+\frac{A_n}{\theta'_n}+\frac{A_B}{\theta_B}+\sum_1^n B_t+B_B \quad \ldots(30)$$

The price problem is solved by comparing equations (29) and (30).

This was the method used in the previous sections for the estimates of price of energy produced by combined systems; and equations (29) and (30) are just a generalization of the method adopted.

Conclusions

Diverging opinions have been expressed on the advisability of using pumped storage to improve the efficiency of large generating systems. Even the advisability or necessity of using pumped storage to balance the production of powerful atomic power stations has been questioned. The writer's intention was to concentrate on this problem.

On the whole it has been proved that the use of pumped storage is of vastly greater importance to a correct balancing of the power generation in large systems than is considered by most specialists. More concentrated consideration should be given to the new technique.

NOTE: This article was submitted as a paper to the Quebec meeting of The Engineering Institute of Canada on May 21, 1958; a shortened version is appearing in *The Engineering Journal* of Montreal.

We wish to draw attention to two errors in Part Two of this article. The twenty-third line down from the top of the right-hand column on page 263, July issue, should read: As $\frac{\Delta N}{\Delta t} \cong \left(\frac{dN}{dt}\right) t'$. The twenty-seventh line should be replaced by:

$$\frac{dN}{dt} = (\theta-\theta_o)\frac{1-\theta_o}{1-\theta}\ t(\theta-\theta_o)/(1-\theta)-1$$

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Fig. 10. General view of project with cofferdam enclosing power-house section

Priest Rapids Development

The design and contractual requirements of this interesting scheme on the Columbia River are described by George S. Schroyer, head of the Mechanical Department, Harza Engineering Company

PART TWO

D. Other Features of the Development. The spillway will be a concrete structure with ogee crest and a flat apron with sill, and has been the subject of model studies at both the Washington State College and the St. Anthony Falls Hydraulic Laboratory. It will contain 22 chain-operated tainter gates each 40 ft. wide by 50 ft. high, manufactured by the Pacific Coast Engineering Co. The spillway will be capable of discharging the design flood of 1,400,000 cusecs with a pool surcharge of 5 ft. above the maximum controlled forebay elevation of 486·5 ft. A bridge over the spillway, with deck at El. 495·5, will provide a 12 ft. wide concrete roadway and a 3 ft. wide walkway.

The spillway bucket as originally conceived consisted of a curved surface with a 50 ft. radius to deflect the water up to the surface of the river downstream of the bucket. The lip of the bucket was at El. 390·5 and the low point of the curved surface at El. 376·0. The St. Anthony Falls model test demonstrated that a flat apron about 75 ft. long at El. 387, with an end sill at El. 391 ft., would produce as good results as the original shape. Since the cost of this section was about one million dollars less than the original section, because of the reduction in rock excavation and concrete quantities, it was adopted.

The left and right embankment sections of the dam are combination earth and rockfill structures consisting of an impervious central core, and upstream and downstream transition sections acting as filters between the core and the pervious shells, as shown in

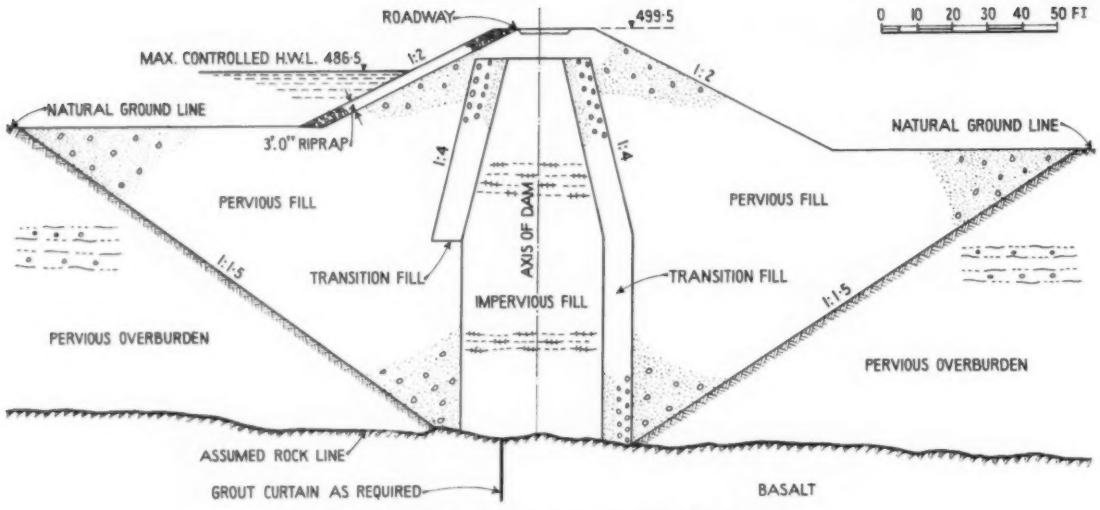

Fig. 11. Typical section through embankment

Fig. 11. The natural gravel and sand overburden is quite porous and must be removed so that the impervious core and transition sections can be carried to bedrock. The crests of the embankments will be at El. 499·5, providing 8 ft. of freeboard above the maximum surcharged pool. Both upstream and downstream faces will have a slope of 2 to 1. A 3 ft. layer of dumped riprap, with rock grading in size from 4 in. to 30 in., will provide wave protection for the upstream slope. Protection for the downstream slope will be provided by coarse gravel. All fill material will be placed in the dry. The impervious core will consist of a sandy silt placed in continuous layers of 1 ft. in thickness and compacted by pneumatic tire rollers. The transition filters will be 9 ft. in width compacted by rollers and will be of material inter-

Fig. 12. General view looking north-east showing excavation

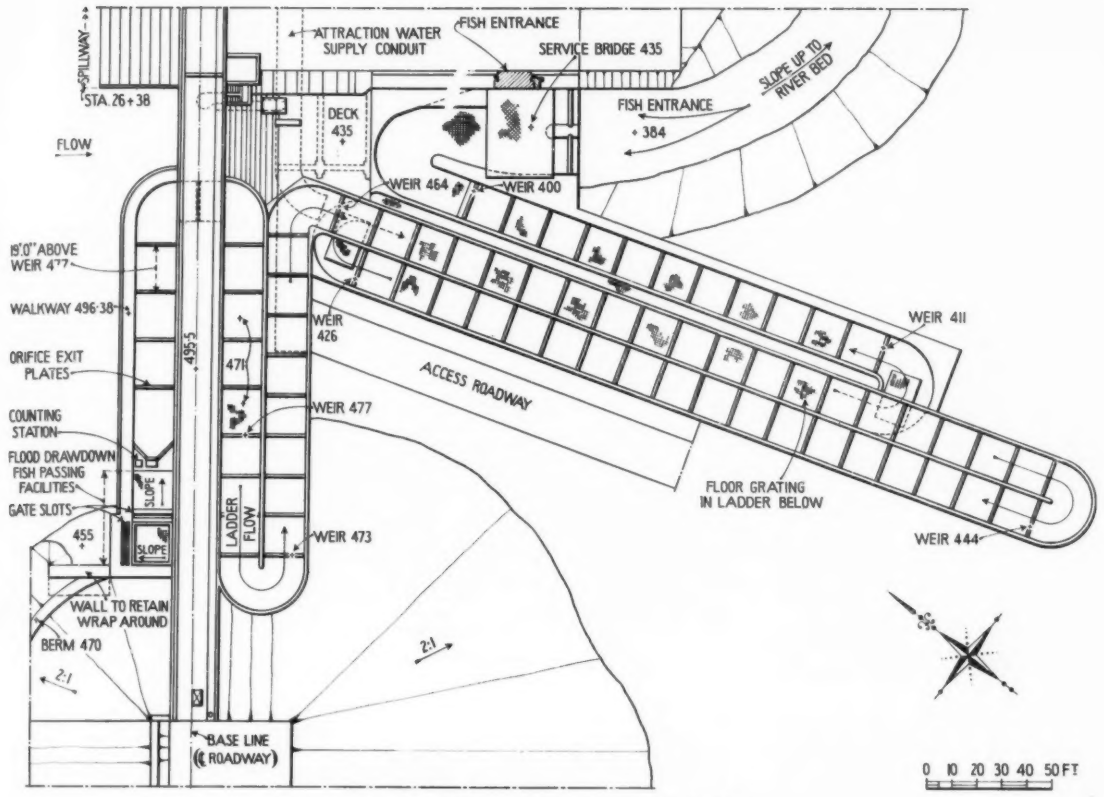

Fig. 13. Plan of right-bank fish ladder

mediate in grading between the core and shell material. The pervious shells will be composed of free draining sand and gravel or rock in sizes $1\frac{1}{2}$ in. and smaller placed in 1 ft. layers and compacted by the normal traffic.

All dams on the Columbia below Chief Joseph have provision for the upstream passage of migratory fish, such as the salmon and steelhead trout, and similar provision will be made at Priest Rapids. The final design of these facilities was made in co-operation with the U.S. Fish and Wildlife Service, and the Washington State Department of Fisheries and Game.

Two fish ladders of reinforced concrete construction will be provided; one at the right end of the spillway, as shown in Fig. 13, and the other at the left end of the power house. Basically, the ladders will consist of a series of pools at 1 ft. increments from tailwater to headwater. Adjustable weirs at both the tailwater and

Fig. 14. Concrete batching and aggregate processing plant

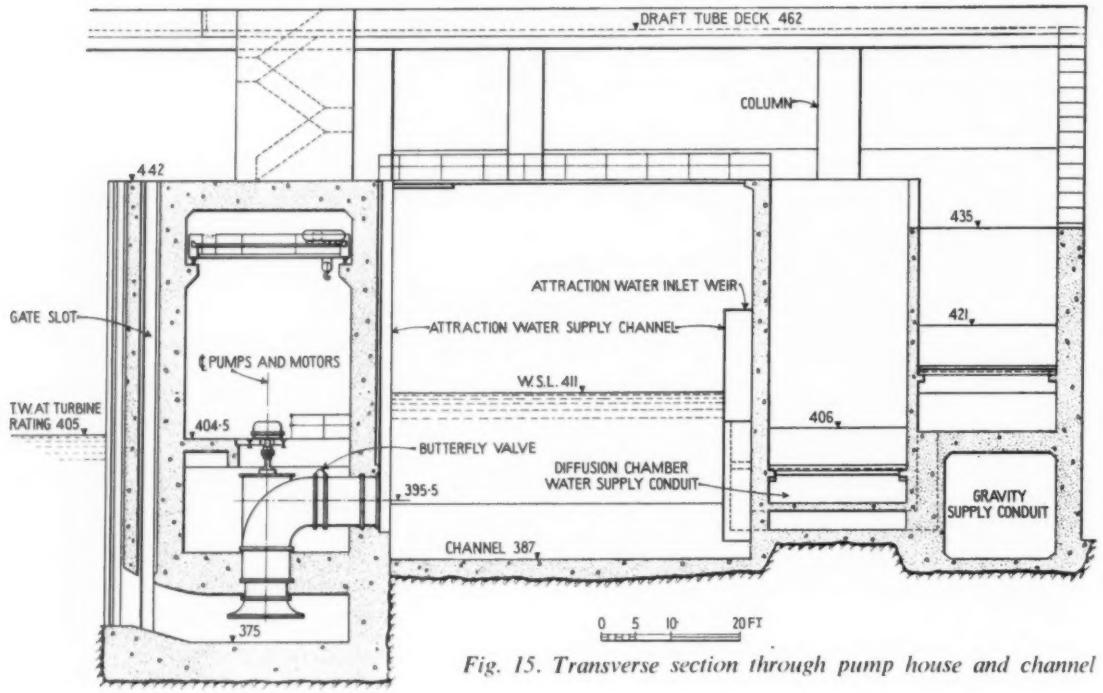

Fig. 15. Transverse section through pump house and channel

forebay levels will allow for fluctuations in water elevation. Water supply for the ladders will be taken directly from the forebay, but this flow will be insufficient to create a velocity at tailwater adequate to attract the fish into the ladders. Consequently, it will be necessary to supplement this supply by pumping water from the tailrace and discharging it into the tailwater entrances to the ladders. Attraction water from the fish pumps will flow the length of the power house in a concrete pressure conduit over the draft tubes and will discharge into the power house fish collection channel through ports in the floor of this channel. The fish-collection channel is actually an extension of the power house fish ladder and fish will enter it through orifices in an adjustable gate over each draft tube and through an entrance at the spillway end of the power house. The pressure conduit will continue from the power house through the spillway structure to the right-bank fish ladder where it will supply the remainder of the pumped attraction water. The pump house itself, Fig. 15, will be an extensive structure, as it will be required to provide approximately 1,500 cusecs of attraction water. The five pumps will be of the fixed-blade axial flow, elbow-discharge type driven by 2,300 V induction motors through gear reducers. Each pump will have a capacity of approximately 300 cusecs at 6 ft. head. The pump house itself will be an indoor type of structure serviced by a bridge crane. Because of the $\frac{7}{8}$ in. spacing of the rack bars protecting the pump intakes, trashraking facilities will be provided. During extreme flood conditions, the entire

Fig. 16. Part of fish facilities and excavation for future unit in right foreground

Fig. 17. General view looking west showing excavation

pump house will be submerged. A flood of this magnitude has not occurred since 1894.

Although extensive rapids downstream from the site severely limit river navigation to high water stages, and the Atomic Energy Commission has placed limitations on private navigation in the river at Hanford, initial provisions for a future navigation lock will be provided on the right bank adjacent to the concrete gravity dam. The anticipated requirements for the lock include a minimum depth over sill of 14 ft., a chamber length of 540 ft. and a width of 86 ft. Initial construction will be limited to the preparation of a base for the future upstream cofferdam around the lock area and to some additional rock excavation adjacent to the gravity dam.

Construction

Construction of the access road was begun by a subcontractor for Merritt-Chapman & Scott Cor-

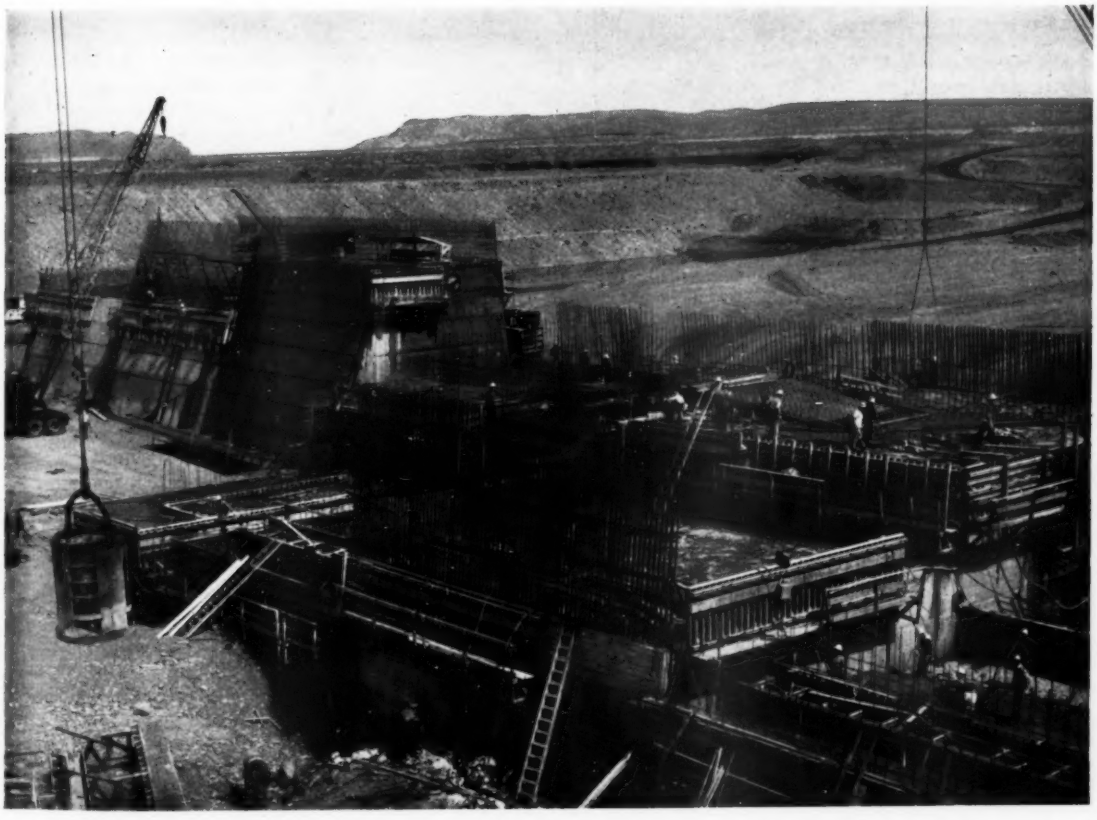

Fig. 18. View looking north-east with concreting work in progress showing part of fish ladder on left bank

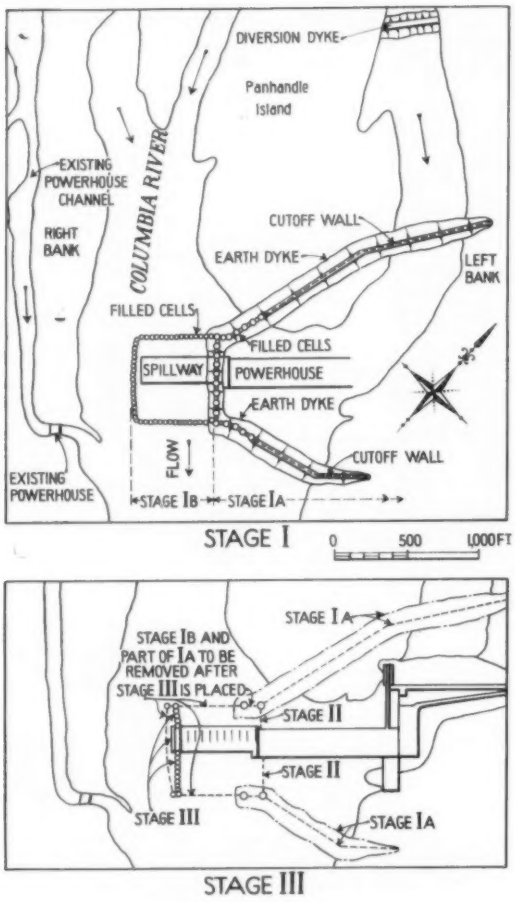

Fig. 19. Diagrams illustrating different stages of the cofferdams required

poration on July 2, 1956, seven days prior to the actual signing of the contract. The major items of work already accomplished are the railroad bridge across the river, the establishment of the construction plant, site grading, and the erection of office and testing facilities, and housing for key personnel. The first stage of the cofferdam construction has been completed, the site of the power house unwatered and the tailrace and power house excavation is in active progress. The first concrete was poured on April 26, 1957, in the fishways gravity-dam area. The cored-out power-house structure up to the intake roof was also completed in 1957 — an extremely fast pouring schedule for such a large structure. The core trench for the left embankment section is completed and fill material is being placed.

The sequence for the cofferdams is shown in Fig. 19. The Stage 1A cofferdam around the power house consists of a combination of earth dike and steel-pile cells completely surrounding the power house. It was constructed in slack water made possible by the previous construction of a diversion dam in the left channel at the upper end of Panhandle Island. After completion of the earth dike, sheet piling was driven through the fill to the rock head, thus forming a cutoff. This was done in those river sections where the current is expected to be moderate. In the more turbulent section toward the middle of the river, cellular sheet-steel cofferdams are being driven through the dike and will be filled with sand, gravel and rock. Construction will be continuous in the power house cofferdam. Half of the spillway will be constructed in a second cellular cofferdam which will be removed before the right-bank cofferdam is constructed, the river being diverted through low blocks in the first half of the spillway. All of the right half of the spillway and the right-bank fish ladder and embankment structure will be completed within this cofferdam. After the removal of this cofferdam, the river will be diverted through the right half of the spillway, and the blocks in the left half will be completed behind floating bulkheads.

Conclusion

The Priest Rapids Development is of extreme interest to those of us who are working on its design. Many problems must be solved before the development goes on the line in the summer of 1960. The project is so large in scope that one short paper can do little more than summarise the highpoints of the history of the project and the progress made up to date.

NOTE. Since the first part of this article was published in the July issue we have been informed that the generator shafts and thrust collars were manufactured by Ruhrstahl A.G., of Essen.

Book Reviews

International Electrotechnical Vocabulary. Publication 50(20): 2nd Edition. Group 20: Scientific and industrial measuring instruments.

I.E.C. Publication 50(20), which has just been issued, contains Group 20: Scientific and industrial measuring instruments, of the Second Edition of the International Electrotechnical Vocabulary which will contain 22 groups when complete. It contains some 345 terms and definitions in French and English, together with the equivalent terms in German, Spanish, Italian, Dutch, Polish and Swedish. Indices are provided for each of the eight languages used. The terms and definitions are divided into the following sections: General terms; detecting instruments; measuring instruments; special recording instruments; integrating instruments; measuring devices and accessory apparatus; constructional elements; characteristic terms; instrument transformers.

Possibilities of Electric Power Exchanges between the Countries of Central and South-Eastern Europe. United Nations Economic Commission for Europe, Geneva, 1958; 40 pp., including 3 annexes and 12 tables. May be obtained from the Sales Section, European Office of the United Nations, Geneva, Switzerland, or through sales agents for United Nations publications. Price $ (US) 0·50, 3s. 6d. stg., 2 Sw. fr., or in local currency.

The ECE Secretariat has published a study on the possibilities of electric power exchanges between the countries of central and south-eastern Europe. The countries so designated are: Albania, Bulgaria, Czechoslovakia, Greece, Hungary, Poland, Romania, Turkey, the Eastern Zone of Germany and Yugoslavia. The study deals in turn with: the conventional energy resources of the countries in the group; their economic situation in regard to population, industrial production, breakdown of production from the various commercial sources of energy, and imports and exports of energy; the present electric power situation in these countries, as regards not only consumption and production, but also electric power transfers; and the electric power prospects. Three annexes to the study provide supplementary information, both on the resources and the energy situation, and the electric power production.

The study stresses that before electro-nuclear power stations come to play a really important part in the European electric power production system there is an urgent need for international action entailing close co-operation between the countries concerned. Any transfers of electric power that may be contemplated between the various countries of the group and also with neighbouring countries should serve to meet the energy deficit of some of them out of the surplus enjoyed by others in a more favourable position. To that end, the study states conclusions of two kinds: some of a general nature suggesting an interconnection system, not only between the grids of the countries of the group, but also between them and the grids of neighbouring countries; others dealing with specific projects which later might be studied more fully.

The BEAMA Catalogue (Fourth Edition), published for The British Electrical & Allied Manufacturers' Association (Incorporated), 36, Kingsway, London, W.C.2, by Iliffe & Sons Ltd. 962 pp. Bound full cloth. Price £6.

The BEAMA Catalogue has long been regarded throughout the world as a buyers' guide to the products and services of Britain's electrical industry. This edition has been produced earlier than usual to make copies available for distribution at the Brussels Universal & International Exhibition, where the British Electrical & Allied Industry has a large collective exhibit in the British Industries Pavilion.

The descriptive catalogue pages have been designed throughout to a standard format, each division being printed in a distinctive second colour. Over 690 pages of profusely illustrated announcements display the products manufactured by member-firms. The divisions are classified as (a) Electrical Power Plant (blue); (b) Electrical Equipment in Industry, Transport and Communications (maroon); and (c) Domestic and Commercial Electrical Appliances, Lighting, Accessories and Installation Material (orange). In addition to the comprehensive Catalogue, separate supplementary volumes of Divisions A, B, and C., including the complete Trade Director of all member-firms have been made available for special use at the Brussels Exhibition.

A Five Language Glossary of technical terms used in the Buyers' Guide is included to help overseas buyers not fully conversant with English terminology. Product headings are listed in English, French, German, Portuguese and Spanish, thus providing a comprehensive cross-reference in five languages. The Classified Buyers' Guide lists under more than 1,300 headings the comprehensive range of electrical and allied equipment manufactured by BEAMA firms. The Trade Directory gives the principal addresses of all BEAMA member-firms in the United Kingdom, subsidiary or branch offices, etc., and over 4,780 names and addresses, grouped territorially, of member-firms' overseas branches, representatives and agents. A list of addresses of the BEAMA overseas committees is also given.

The Theory of Marginal Cost and Electricity Rates. The Organisation for European Economic Co-operation, 2 rue André-Pascal, Paris XVI. 79 pp. 16 ff. Price 6s. 6d., $1·25, 400 Fr. fr.

The theory of price formation on the principle of marginal cost has been discussed by economists for many years. Briefly, marginal cost means the cost of producing an additional unit, and in terms of electricity supply it means the cost of power produced by additional plant installed for that purpose. Although this method of costing does not yet appear to have been applied to electricity supply, the O.E.E.C. group of experts, without committing themselves to any recommendation, felt that it would be useful for governments, public authorities and electricity undertakings to have at their disposal a general survey of the system, and appointed a working party to prepare such a survey. The report under review is divided into two parts, the first of which consists of a theoretical study of marginal costing by the working party concerned.

Chapter I outlines the scope of the study and distinguishes two ways of visualising sale at marginal

cost: first, in relation to the determination of the average level of prices, and secondly, having regard to price differentials varying with the characteristics of the power supply. For better clarity, a number of definitions relating to the electricity supply industry are given in Chapter II. In view of the variations in electricity demand according to the hour of the day and the time of the year, Chapter III discusses marginal costs allowing for periodical fluctuation. All these theoretical considerations are illustrated in Chapter IV by three practical examples. The first, and most simple, refers to thermal production; the second, referring as it does to hydro production, is complicated by an additional factor, viz., the uncertainty and irregularity of hydro conditions. The third example, i.e., a system involving both hydro and thermal plant, is still further complicated by the need to co-ordinate the output of the thermal and hydro components. This part of the report finally discusses the arguments for and against the application of the theory of marginal cost to electricity rates and draws attention to the difficulties this involves in actual practice.

In Part Two are examined the practical methods used for establishing electricity rates in the following countries: Germany, Austria, Belgium, France, Italy, Norway, the Netherlands, the United Kingdom, Sweden and Switzerland.

Memento d'Hydraulique Pratique. By J. Valembois. Collection du Laboratoire National l'Hydraulique. Eyrolles Editeur, 61 Boulevard Saint Germain, Paris V. 1958. 108 pp. Price 950 fr. net.

This book has been conceived on quite unusual lines. It does not set out to be a text book on hydraulics, nor a bibliographical reference book, nor an engineer's pocket book in the normal sense, but it is intended rather as a collection of memoranda for the use of engineering students. It aims to provide a conspectus of hydraulics to enable the student to plan his studies, to indicate documentary and other sources of information, and to pinpoint the essentials of each branch of hydraulic study. Guidance is given as to the field of application of any particular result, orders of magnitude of important values (e.g., coefficient of viscosity), systems of units, and so forth. In view of its character the book does not profess to provide anything approaching a complete coverage of the subject, but it sets forth the salient considerations governing the physical properties and statics of fluids, the various types of flow, model testing, and hydraulic measurements. No mention is made of hydraulic machinery of any kind, the subject matter being devoted to what might be termed pure as opposed to applied hydraulics.

Das Pumpspeicherwerk Reisach-Rabenleite (The Reisach-Rabenleite Pumped Storage Works). Compiled and edited by Dipl.-Ing. Hautum in co-operation with Dipl.-Ing. Naber and Ing. Etzel. Published by Energieversorgung Ostbayern A.G., Regensburg, Prüfeningerstrasse 20, Bavaria; 8½ in. by 12 in., 420 pp., 324 ff., 30 folded plates. Price in Germany, cloth bound, DM.50.

Issued by the owners of the Reisach-Rabenleite plants, which constitute the major section of the Pfreimd river development, this uncommonly handsome book goes far beyond the scope of a house publication. Most of the articles it contains are of general interest and would be a credit to any work dealing especially with the planning and construction of hydro-electric developments including pumped-storage installations.

As planned by Energieversorgung Ostbayern A.G. (East-Bavaria Power Supply Co. Ltd.), the development, when completed, will include a further power plant, Tanzmühle, now in course of construction. The backbone and perhaps the most interesting feature of the whole scheme, is the pumped-storage reservoir, 1·5 million cu. m. in capacity and 180 m. above the river between the Reisach and Tanzmühle power stations. The system is completed, upstream, by the Kainzmühl reservoir and dam, and, downstream, below the Reisach plant, by the Trausitz reservoir; the difference in level between these two reservoirs is 56·6 m.

The various technical aspects of the project are dealt with in part 3, and the mechanical and electrical equipment, as well as the various phases of the construction work, in parts 4 and 5 respectively. It is somewhat embarrassing to single out any of the purely technical articles, but we should like to draw attention to the following: "Geological and Technical Factors which affected Tunnelling and Shaft-excavating Work at the Pfreimd Pumped-storage Plants," by Chief-Inspector of Mines G. Schwarz, Amberg; "Static Considerations on Prestressing by Grouting," by Dipl.-Ing. F. Glötzl, Karlsruhe; "Model Tests effected in Connection with the Hydraulic Works of the Reisach-Rabenleite Pumped-storage Scheme," by Dipl.-Ing. P. G. Franke, Munich. In part 5, Head Engineer Bayer's article on construction work and tunnelling at the Reisach installations should prove of special interest to the tunnelling expert, including as it does a detailed description of the Rabenleite vertical shaft. The interesting features of the Rabenleite storage reservoir and the difficult construction work involved are described in two articles, one by Dipl.-Ing. F. Hautum and the other by Dipl.-Ing. R. Beck. The latter article, together with another article by Dipl.-Ing. Hautum, also deals with the Reisach tunnel. The comparative survey of this tunnel with the Santa Massenza and the Errochty tunnels is of particular interest, the similarity of the Reisach and Errochty layouts being striking. The two generating-pumping sets at Reisach consist each of a 47,000 h.p. Francis turbine, passing 22·5 cu. m. per sec. from a head of 166 to 186 m., a two-stage two-flow storage pump with fixed guide wheel, lifting 14·5 cu. m. per sec. to 170 and 190 m., a 35,000 kVA synchronous generator, and a starting turbine, all machines being mounted on a horizontal shaft.

Annuaire Hydrologique de la France, 1956. Société Hydrotechnique de France, 199 rue de Grenelle, Paris VII. 252 pp. Price 2,500 fr. net.

This annual publication gives the usual detailed hydrological data for the catchment areas of France for 1956. Seven new stations were established during the year, at Chooz, Edelweiss, Portet, Malause, Licq Atherey, Angoustrine, and la Mulatière, and details of these stations are collected in a table. There is also a note on the effect of the commissioning of Pragnères hydro-electric station on the Luz gauging station, which has lost some 50 sq. km. of catchment area. A list of the 716 gauging stations now in service in France is included.

Fig. 14. Dresser-coupled penstock, 80⅝ in. diameter, on concrete saddles. Pipe sections are deflected in the couplings to accommodate the ground profile

Power Penstocks

Analysis of various penstock designs and construction methods by P. J. Bier, Consulting Engineer, formerly in charge of penstock design of the U.S. Bureau of Reclamation

PART THREE

Design "C"

Dresser-coupled field girth joints and 120° saddle supports; shell thicknesses are proportioned for the internal pressure and circumferential bending at saddle supports.

Description. This penstock design is shown in Fig. 14. It is identical with that shown in Fig. 7 using two types of steels. (According to Arriaga's analysis, which is discussed in Design " B," the stresses due to circumferential bending at the saddle supports may be disregarded in pressure pipe and need not be added to the stresses due to internal pressure when determining the shell thicknesses.)

The shell thicknesses are computed for the combined stresses and range from ⅜ in. at the upstream end to $1^{1}/_{16}$ in. at the downstream end, using design stresses of 13,750 and 17,500 lb. per sq. in. respectively, for the A285 gr. C and the A212 gr. B steels. As all welds in the pipe shell are subjected to radiographic inspection a joint efficiency of 90% is used with net design stresses of 12,375 and 15,750 lb. per sq. in. for the two steels. The portion of the penstock at the downstream end, which is fabricated from $1^{1}/_{16}$ in. plates, will be stress relieved. This increases the joint efficiency to 95%, permitting a net design stress of 16,625 lb. per sq. in. in computing the shell thickness.

Like Design " B " the penstock will be shop fabricated in 40 ft. erection lengths and will be provided with Dresser coupled field girth joints as shown in Fig. 8. Reinforced concrete support piers of the saddle type with 120° contact and spaced at 40 ft. centres are used. All pier and anchor designs are identical with those shown on Design " B."

Fabrication, testing, installation and painting are identical with Design " B."

Design "D"

Dresser-coupled field girth joints and ring girder supports, with sliding base on concrete piers.

Description. This penstock design is identical with Design " B " shown in Fig. 7 using types A285 gr. C and A212 gr. B steel with the exception that ring girders are used at the points of support. The piers are designed with two support points provided with base castings machined at the top to support the machined bearing plates welded to the ring girders to facilitate sliding. Single ring girders are used which are welded

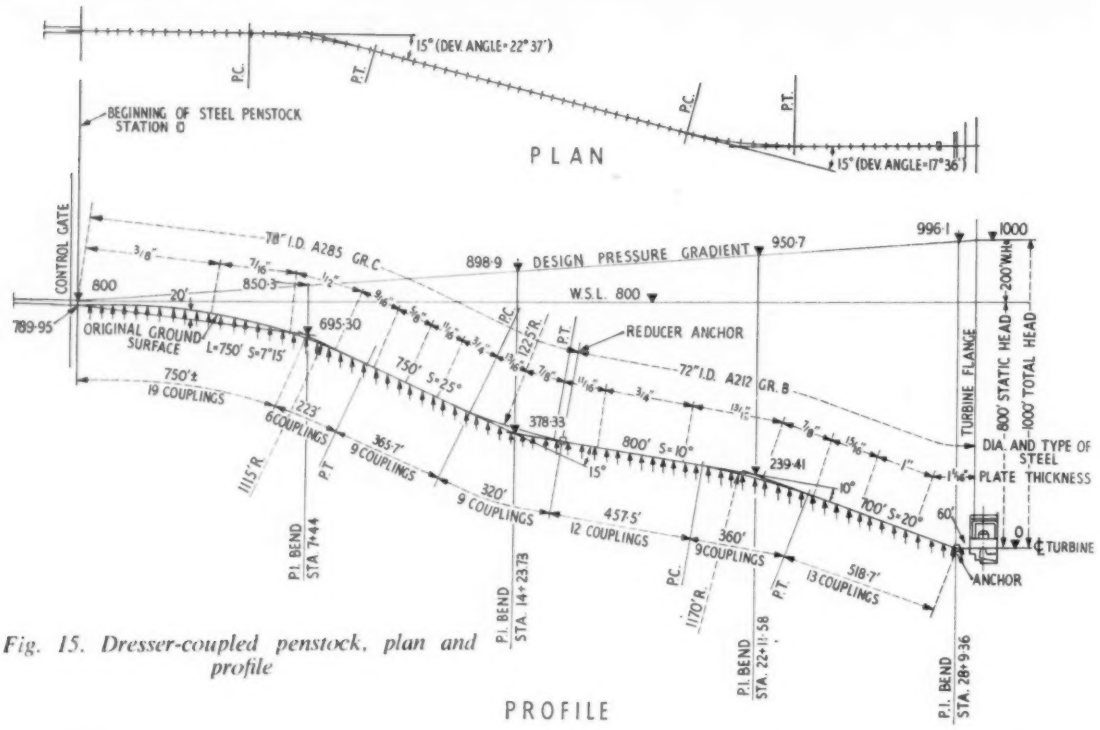

Fig. 15. Dresser-coupled penstock, plan and profile

and braced to the pipe shell as shown in Fig. 15 to resist the longitudinal forces. The base castings are grouted into the pier tops after the penstock is set in place and are anchored into the pier with bolts in pipe sleeves to permit adjustments in the bolt setting. Guide vanes in the base castings will keep the penstock aligned transversely and will resist lateral forces acting on the pipe, especially when empty.

The penstock will be shop-fabricated in 40 ft. erection lengths which will be connected with Dresser couplings as shown in Fig. 8. Reinforced concrete support piers spaced at 40 ft. centres will be used. The penstock shell is proportioned for the internal pressure due to static head and water hammer as plotted in the profile in Fig. 7. All welds in the pipe shell are radiographed, and joint efficiencies and design stresses are identical with those used for Design B. Consequently the same plate thicknesses are used as shown in Fig. 7.

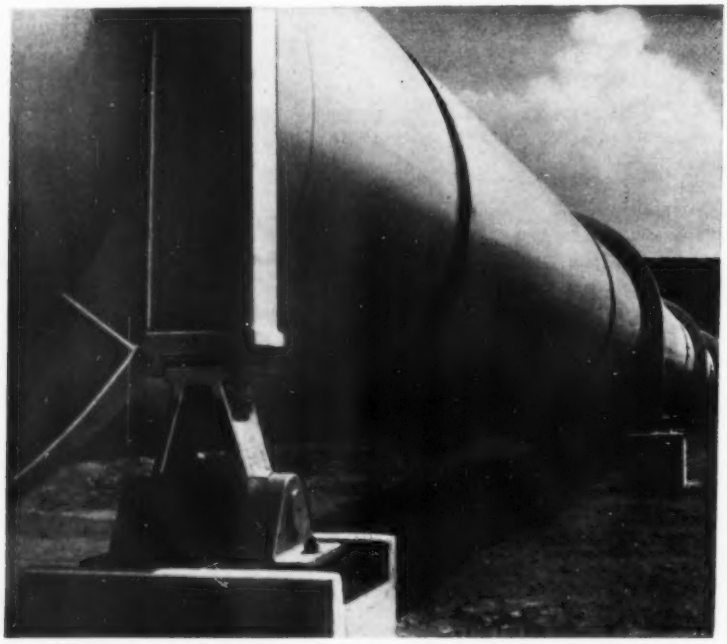

Fig. 16. Welded steel penstock, 104 in. diameter, Owens River Gorge, Los Angeles

Support Piers. The support piers are designed for a differential sliding coefficient of 0·25 based on a coefficient of 0·50 on one side and 0·25 on the opposite side of the pier as determined by tests.[5] A summation of the vertical loads and longitudinal forces gives a resultant which intersects the pier base in its middle third as illustrated in Fig. 16. For the combined bends where the forces are active in both the longitudinal and lateral directions, a pier design was developed as shown in Fig. 17. The girder is identical with that shown in Figs. 15 and

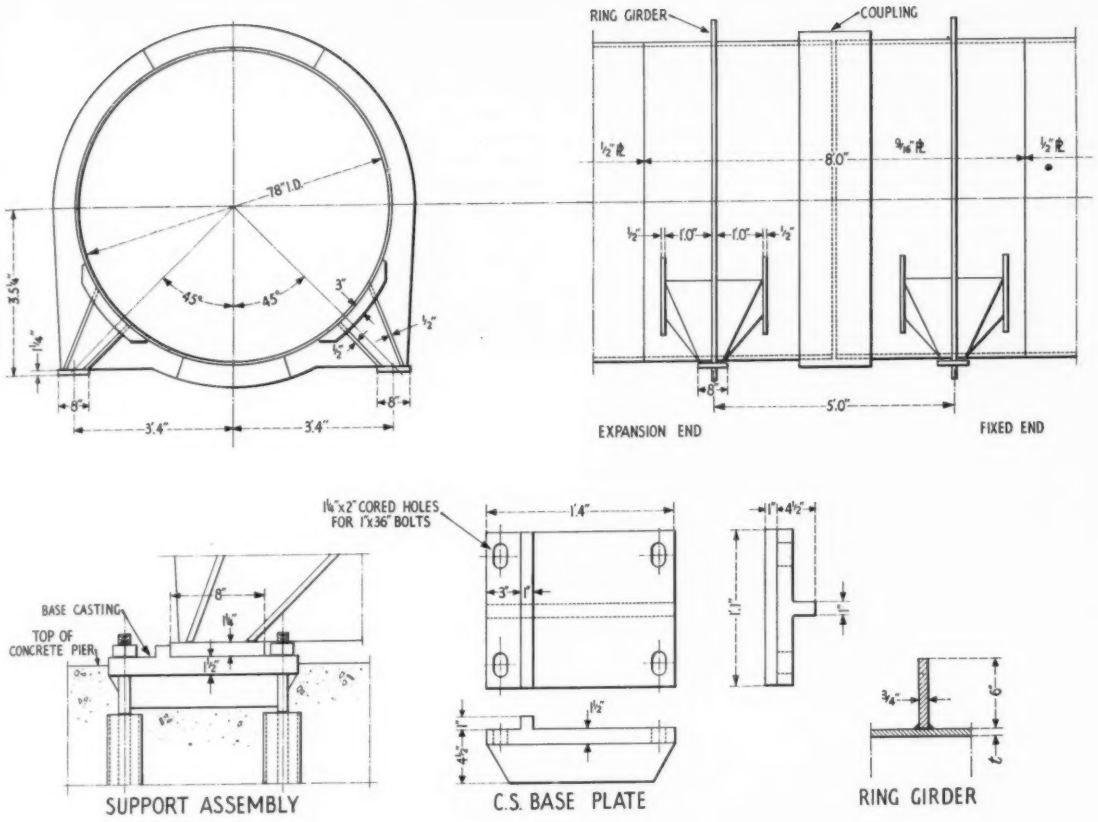

Fig. 17. Ring-girder support of the sliding type

Fig. 18. Sliding-type ring-girder supports. Baseplates are ready to be grouted into the pier

16 except that a cover plate was welded on it at the arc of contact with the pier to transmit the loads and forces to the concrete. A curved bearing plate matching this cover plate will be concreted into the pier top to reduce the frictional forces on the pier due to temperature movements of the penstock section. The ring girder is free to move on the bearing plate at all sliding type supports, but will be welded to the bearing plates at the fixed-type supports to provide the required anchorage. Braces are welded between the pipe shell and the cover plate to resist the longitudinal forces.

The concrete anchors are identical with those shown for Design "B."

Fabrication, testing, installation and painting are identical with Design "B."

Comparative Cost Estimates of Penstock Designs

Tables I to V give the estimated construction cost of each type of penstock design. The costs are based on the designs prepared for each type, using, as far as possible, unit costs from recent bids received for similar constructions. The welded and riveted penstock shows the highest construction cost and the coupled penstock indicates the lowest cost with an indicated saving of from 7 to 16% for the various coupled designs as compared to the welded-riveted design. This is due mostly to the greater weight, and the higher fabrication and installation cost of the welded-riveted construction, as compared to the coupled penstock, although the cost of piers is much greater for the coupled penstock.

Fig. 19. Coupled penstock, 70 in. diameter, for 2,000 ft. head, on welded steel saddles. Coupling bolts are being tightened with torque wrenches

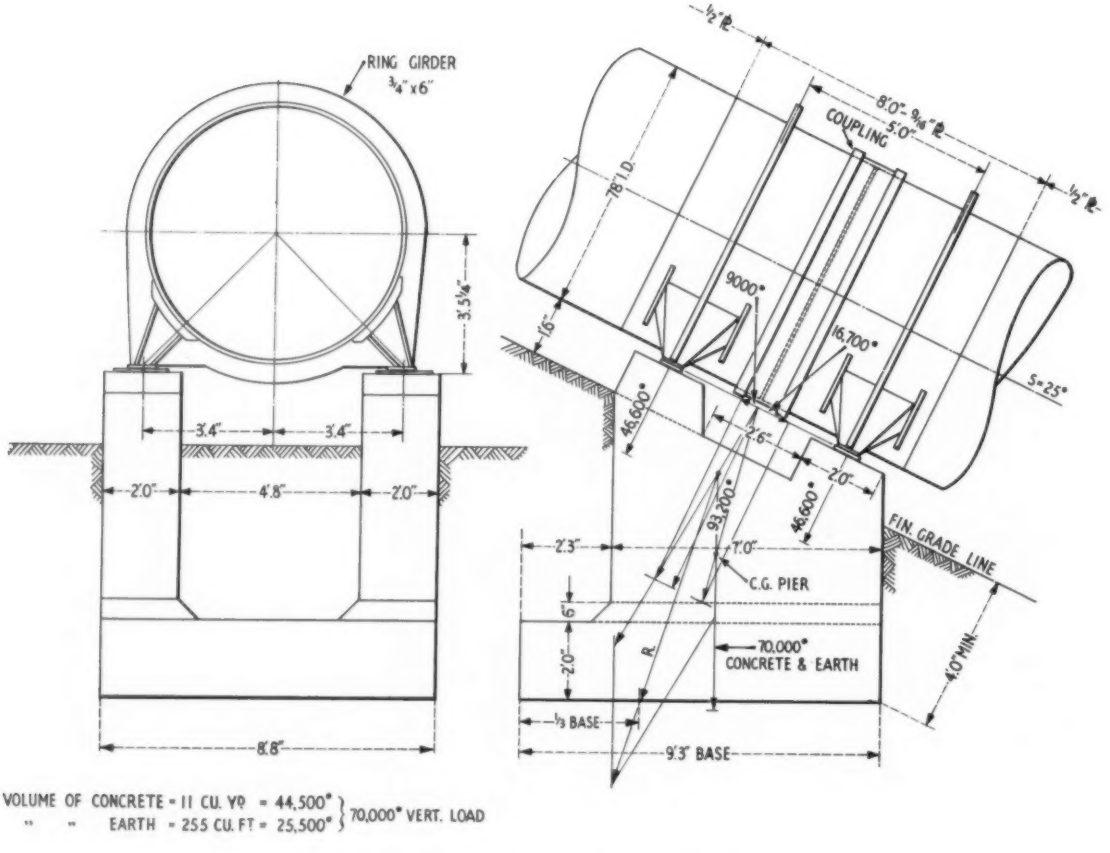

Fig. 20. Typical support pier for ring girder

TABLE I. COMPARISON OF ESTIMATED COSTS OF PENSTOCK DESIGNS

Item	Design "A" Welded-riveted	Design "B" Coupled saddle supp.	Design "C" Coupled saddle supp.	Design "D" Coupled girder supp.
	$	$	$	$
Pipe sections and girders	462,480	348,300	401,940	426,080
Pipe coating	31,847	29,245	29,245	29,721
Installation	156,480	78,600	91,000	84,750
Couplings—installed	—	19,300	19,300	19,300
Concrete piers	22,638	89,012	89,012	71,610
Concrete anchors	21,142	9,114	9,114	9,114
Reinforcement steel	8,250	18,750	18,750	15,375
Excavation	14,574	4,785	4,785	4,125
Backfilling	1,144	2,123	2,123	1,815
Compacting backfill	3,432	6,369	6,369	5,445
Total installed cost	721,987	605,598	671,638	667,335
Saving over welding		116,389	50,349	54,652

TABLE II. WELDED AND RIVETED PENSTOCK—DESIGN "A"

Item	Quantity	Unit	Unit cost	Item cost
			$	$
3,060 ft. of 78 in. and 72 in pipe, all of A285 steel, delivered in 40 ft. sections	1,927,000	lb.	0·24	462,480
Shop cleaning and painting of interior with spun enamel	60,200	sq. ft.	0·17	10,234
Completing and repairing 20% of interior coating in field	12,040	sq. ft.	0·33	3,973
Field applied exterior aluminum coating	63,000	sq. ft.	0·28	17,640
Installation of pipe (handling, placing, welding, riveting)	1,956,000		0·08	156,480
Concrete work				
48 support piers at 60 ft. centres	294	cu. yd.	77·00	22,638
5 anchors	341	cu. yd.	62·00	21,142
Reinforcement steel	55,000	lb.	0·15	8,250
Earthwork				
Excavation of upstream end hill	15,000	cu. yd.	0·80	12,000
Excavation for piers and anchors	1,560	cu. yd.	1·65	2,574
Backfilling	1,040	cu. yd.	1·10	1,144
Compacting backfill	1,040	cu. yd.	3·30	3,432
Total installed cost				721,987

TABLE III. COUPLED PENSTOCK—DESIGN "B"

Item	Quantity	Unit	Unit cost	Item cost
			$	$
1,660 ft. of 78 in. pipe of A285 steel, delivered in 40 ft. sections	663,000	lb.	0·21	139,230
1,395 ft. of 72 in. pipe of A212 steel, delivered in 40 ft. sections	909,000	lb.	0·23	209,070
Installation of 3,055 ft. pipe (handling, placing, etc.)	1,572,000	lb.	0·05	78,600
Shop cleaning and painting interior with spun enamel	60,200	sq. ft.	0·17	10,234
Repairing 10% of interior shop coating in the field	6,020	sq. ft.	0·33	1,987
Field cleaning and painting exterior with aluminum	60,800	sq. ft.	0·28	17,024
Dresser Style 38 couplings, installed	78			19,300
Concrete work				
74 support piers at 40 ft. centres	1,156	cu. yd.	77·00	89,012
3 anchors	147	cu. yd.	62·00	9,114
Reinforcement steel	125,000	lb.	0·15	18,750
Earthwork				
Excavation for piers and anchors	2,900	cu. yd.	1·65	4,785
Backfilling	1,930	cu. yd.	1·10	2,123
Compacting backfill	1,930	cu. yd.	3·30	6,369
Total installed cost				605,598

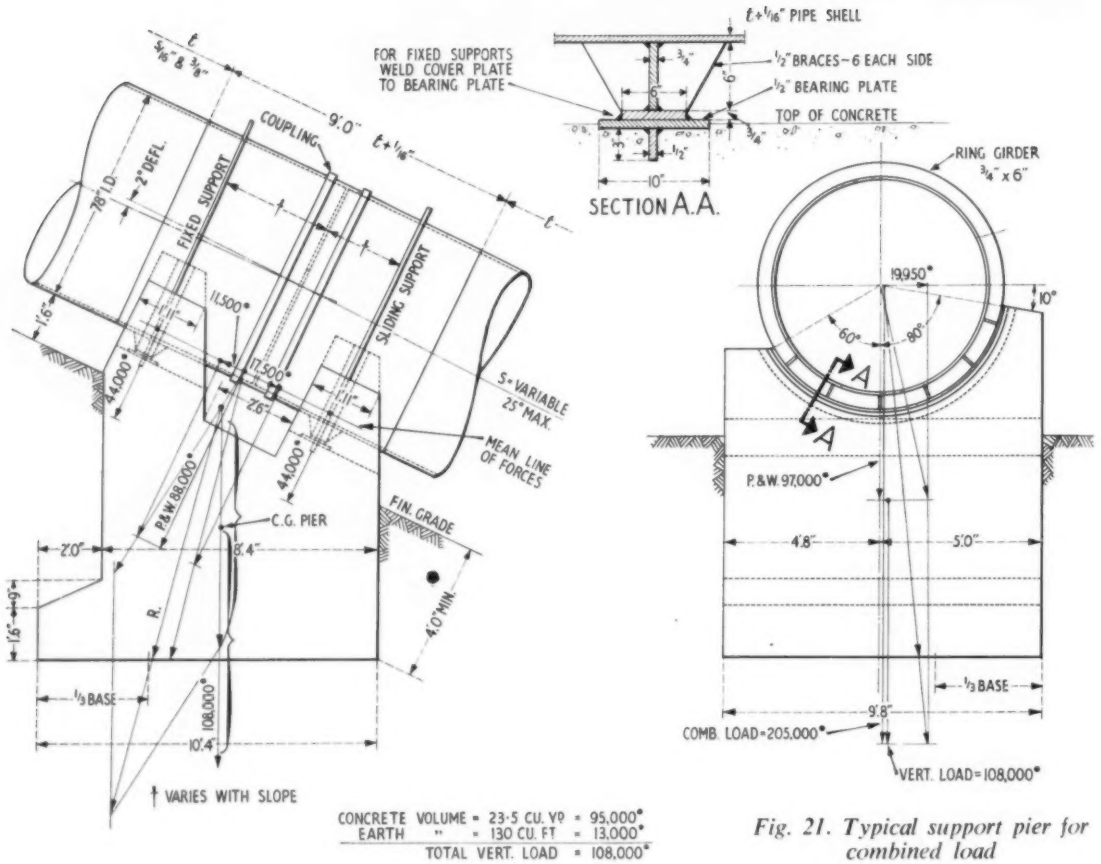

Fig. 21. Typical support pier for combined load

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[3] Tests of Cylindrical Shells, University of Illinois, Bulletin No. 331, 1941.

[4] The Influence of Circumf. Tension on the Transverse Bending of a Pressure Conduit on Concrete Masonry Supports, by Pablo H. Arriaga.

[5] Penstock Bulletin, National Electric Light Association, 1923.

TABLE IV. COUPLED PENSTOCK—DESIGN "C"

Item	Quantity	Unit	Unit cost	Item cost
			$	$
1,660 ft. of 78 in. pipe of A285 steel, delivered in 40 ft. sections	833,000	lb.	0·21	174,930
1,395 ft. of 72 in. pipe of A212 steel, delivered in 40 ft. sections	987,000	lb.	0·23	227,010
Installation of 3,055 ft. of pipe (handling, placing, etc.)	1,820,000	lb.	0·05	91,000
Shop cleaning and painting interior with spun enamel	60,200	sq. ft.	0·17	10,234
Repairing 10% of interior shop coating in the field	6,020	sq. ft.	0·33	1,987
Field cleaning and painting exterior with aluminum	60,800	sq. ft.	0·28	17,024
Dresser Style 38 couplings, installed	78			19,300
Concrete work				
74 support piers at 40 ft. centres	1,156	cu. yd.	77·00	89,012
3 anchors	147	cu. yd.	62·00	9,114
Reinforcement steel	125,000	lb.	0·15	18,750
Earthwork				
Excavation for piers and anchors	2,900	cu. yd.	1·65	4,785
Backfilling	1,930	cu. yd.	1·10	2,123
Compacting backfill	1,930	cu. yd.	3·30	6,369
Total installed cost				671,638

TABLE V. COUPLED PENSTOCK—DESIGN "D"

Item	Quantity	Unit	Unit cost	Item cost
			$	$
1,660 ft. of 78 in. pipe of A285 steel, delivered in 40 ft. sections	731,000	lb.	0·24	175,440
1,395 ft. of 72 in. pipe of A212 steel, delivered in 40 ft. sections	964,000	lb.	0·26	250,640
Installation of 3,055 ft. of pipe (handling, placing, etc.)	1,695,000	lb.	0·05	84,750
Shop cleaning and painting interior with spun enamel	60,200	sq. ft.	0·17	10,234
Repairing 10% of interior coating in the field	6,020	sq. ft.	0·33	1,987
Field cleaning and painting exterior with aluminum	62,500	sq. ft.	0·28	17,500
Dresser Style 38 couplings, installed	78			19,300
Concrete work				
74 support piers at 40 ft. centres	930	cu. yd.	77·00	71,610
3 anchors	147	cu. yd.	62·00	9,114
Reinforcement steel	102,500	lb.	0·15	15,375
Earthwork				
Excavation for piers and anchors	2,500	cu. yd.	1·65	4,125
Backfilling	1,650	cu. yd.	1·10	1,815
Compacting backfill	1,650	cu. yd.	3·30	5,445
Total installed cost				667,335

Communications and Control at Snowy Mountains

The N.S.W. Electricity Commission will establish high-frequency radio communication channels between its System-Control Centre in Sydney and the Snowy Mountains hydro-electric control station at Cabramurra.

Initially, the communication channels will be superimposed on the Commission's own power lines for the greater part of the distance, and partly by direct radio beams between communication towers, 150 ft. in height. The power line carrier sections will be those already operating between Sydney, Tallawarra, and Goulburn, and those to be installed on the new 330,000 V transmission line now being built by the Commission from Yass to the Upper Tumut area.

The intervening Goulburn to Yass section will be linked by ultra high frequency radio beams via a repeater station at Lerida (near Collector). It is anticipated that direct radio communications will ultimately be established over the whole distance, and also with the Commission's control centre in Melbourne.

The hydro-electric stations built by the Snowy Mountains Authority will be provided with operating staff by the Electricity Commissions of N.S.W. and Victoria, which will share the electricity made available. Immediate communications are consequently essential to control the combined output of the Snowy Mountains stations according to the most economic power production requirements of the State systems. This is particularly necessary because the Snowy Mountains stations will largely operate at peak-load periods, and even when the scheme is completed 85 per cent. of the total electrical energy required will be produced by the States themselves, chiefly at thermal power stations.

The radio links will operate on a frequency of about 2,000 megacycles (about 10 times that of the upper television frequencies) and provide "line of sight" communications in both directions. Reason for using such very high frequencies is to permit the use of a large number of separate channels within the chosen frequency range. Speech transmission is only a relatively small part of the communications system being installed. Many separate channels will be used for remote switching, supervision of the system, the operation of protective devices, and for metering.

Already a substantial part of the Commission's State supply system has been or is being linked up by communication channels of this kind, both to improve the reliability of the Commission's transmission network and to ensure the most economic order of power station operation to meet the total demand.

The new communications link-up will be ready for the initial operation of the first of the major Tumut stations in the winter of 1959.

The "carrier" section between Cabramurra and Yass will be installed at the same time as the high voltage power lines are erected. The communication towers for the direct U.H.F. radio section are already erected at Goulburn and Lerida, and the Yass tower will shortly be installed and ready for testing.

Mobile Handling Equipment. A number of publications issued by I.T.D. Limited give particulars of a comprehensive series of mechanical handling units, including fork lifts and platform trucks, which can be adapted to suit almost every kind of handling problem. I.T.D. Limited is a relatively new organisation by which the Clark Equipment International Company of America entered into partnership with the Austin Motor Company and Crompton Parkinson Limited to produce mechanical handling equipment of all kinds.

Northwest Power Industries Limited, Canada. In future the address of J. M. Wardle, Consulting Engineer, will be Northwest Power Industries Limited, Room 602, 88 Metcalfe Street, Ottawa, Ontario, Canada. The telephone number is CEntral 2-5701.

CIGRE, 1958

A survey is given of those papers likely to be of interest to readers of this journal

THE 17th meeting of CIGRE—the International Conference on Large Electric Systems—met in Paris in June, and attracted more delegates than ever before. Some 140 papers were discussed, and these were divided into 14 sections. In addition, the Study Committees of every section met during the ten days of the conference, including those sections which, by a relatively new CIGRE rule, are discussed once every four years.

In the alternator section of this year's meeting, perhaps the feature of most interest to hydro-electric engineers was the emphasis given to the use of electronic exciters for hydro-electric machines. This subject was mentioned in a Swiss paper by MM. W. Frey and R. Nozer, of Brown Boveri, who concluded that rectifiers now constitute perfectly reliable exciters. When large alternators are used machines driven off the main shaft cannot always supply the exciter with sufficient power. Modern standards of stability involved more serious problems affecting the excitation and control of the very large machines now being built. The paper gave details of full-scale tests on a 7,000 kVA machine, and showed the great advantage of very rapid de-excitation by changing over the grid-controlled rectifier from rectifier to inverter operation.

A Russian paper, added to the list after the conference had opened, dealt in some detail with the electronic exciters now in service on nine of the large units of the Kuibyshev plant. This paper stated that after lengthy experiment, the advantages of the electronic excitation system were fully proved in service. These exciters were capable of providing a high rate of voltage build-up, even reaching 80,000 V per second. As with the Swiss design, the decay of the excitation voltage and generator field quenching were achieved by the change-over of the mercury-arc equipment from rectifier to inverter operation, the advantage being that the excitation circuit was never broken. A 500 W regulator was sufficient to control a modern generator automatically, although about 150 kW would be necessary for older equipment.

The cost of electronic exciters was about 50% lower than for normal equipment, and there was another important constructional advantage. Because the exciter was no longer placed on top of the generator houses the height of the whole unit could be 1·5 metres lower, and this would obviously affect the height of the crane and of the building itself.

Quick-response excitation made it possible to reduce substantially the size and weight of the generators. One of the most effective methods of improving steady-state and transient response to line conditions was to decrease the synchronous and transient reactance of the generator as well as to increase the flywheel effect. With quick-response electronic gear, artificial decrease in reactance values and the increase in flywheel effect would no longer be necessary to obtain system stability. The structure could be smaller and the cost would be some 20% less in consequence.

During the generator sessions there was some reference to the constructional aspect of generator practice. In view of the high cost of transmission lines for very high voltages, should the generators still provide the necessary reactive power or would it be more economical to produce this power near the centres of load? During the discussion it appeared that for large systems it was now certainly desirable to install means of generating reactive power at the receiving end of the transmission system. In Sweden, capacitors were used satisfactorily on the smaller sites, and for large schemes Swedish engineers were standardising on 100 MVAR synchronous condensers. (In Great Britain, although not a hydro-electric country, the same problem has arisen and synchronous condensers of 40 MVAR are to be installed near large centres of load in the future.)

Several papers and contributors to the discussion on alternators touched on the asynchronous operation of machines. This system has certain advantages, particularly in the case of hydro-electric generators where damping windings are usually found. Some practical experience had been gained on machines designed in Hungary, and this was mentioned in a paper by Messrs. Kovacs and Csaki. However, it seemed that heating would limit operating time for machines running asynchronously.

The transformer session had as one of its principal themes the question of transporting the very large units required to match the large generators now under construction. Although many countries have concentrated on the use of single-phase units for the higher voltages, there is nowadays a swing towards the employment of 3-phase units which can be made up to 500 MVA. This trend has been influenced by the considerable reduction in the cost of the core materials for a 3-phase unit as opposed to three single-phase units of the same total nominal capacity, and the reduced iron losses have also to be considered.

In some cases, however, restricted transport facilities, particularly to remote hydro-electric sites, made it necessary to consider dismantling the transformer after erection and testing it in the manufacturer's works, and this involved the question as to what tests would be required on site after re-assembly. During the discussion, Dr. W. Schaffer, of A.E.G., Frankfurt, said that such re-assembled transformers should undergo complete factory tests before commission. Other delegates, however, took the view that a simple overvoltage test would be sufficient, and that impulse testing could not be carried out on site without great increase in costs, delay and uncertainty as to accuracy.

Nevertheless, Dr. Schaffer still maintained that it was so important to test the transformer properly that if site testing could not be carried out it was better to use smaller units which could be shipped complete to the site.

The special reporter of the transformer section decided that the general increase in the generating plant connected to practically every system made the behaviour of transformers under heavy short-circuit current conditions increasingly important. There were a number of papers on this subject, including one from three French engineers, MM. A. Pichon and B. Hochart of Alsthom and F. Salgues of Electricité de France. These authors evolved first a mathematical study of the conditions in a transformer under short-circuit, and then gave the results of a series of measurements and tests taken over a considerable period. This paper was regarded as a valuable contribution to the subject, but it was felt in the discussion that there was still insufficient knowledge about the properties of transformer copper under heavy and repeated stress after a lengthy period of service. It was stated that these mechanical properties depended very largely on the presence of minute quantities of impurities, which conditioned the re-crystallisation of the metal and that this was a subject on which much further research could profitably be carried out.

The circuit-breaker session was largely concerned with somewhat theoretical considerations relating to the design of circuit-breaking devices, particularly in the light of experience now being gained on the testing stations established in various countries. From the operating engineer's point of view the main subject of interest in this group of papers was that of operating experience with ultra-rapid reclosing. A paper by Messrs. J. H. Kinghorn, H. C. Barnes and A. Hauspurg of the American Gas and Electric Service Corporation, U.S.A., showed that on a 345 kV network equipped with ultra-rapid reclosing breakers, mainly of the bulk oil type but with two air-blast breakers, experience had been extremely satisfactory. The breakers had a tripping time in the range of 5 to 8 cycles, and a dead time of 10 to 13 cycles. The paper then gave the result of experience over two years; there had been 152 operations, with the number of successful reclosures lying between 90% and 100% for the different parts of the system. Since hydro-electric engineers have to deal with transmission lines which generally run across extremely exposed terrain, the American paper mentioned a point concerning lines from water-power stations which are particularly affected by two adverse conditions, lightning and sleet. The former is dealt with successfully by the automatic reclosure system but this does not always provide a satisfactory remedy for sleet. Further research is in progress to ascertain the cause for this difference.

In the session on insulating oils and material, three engineers from the Oerlikon Company of Switzerland reported on the successful use of synthetic insulation for the stator bars of large machines. This material, made from modified and polymerised epoxides, can provide a complete guarantee against generator insulator failure under ageing or thermal stresses.

The remote control of water-power stations and substations was considered in a paper presented by Messrs. von Geijer, Nordstrom and Bergman of the Swedish State Power Board. They showed conclusively that substantial economies could be secured and a reduction in labour effected by introducing remote-control systems. In the introduction to their paper, they stated that certain hydro-electric plants in Sweden were situated in unpopulated areas. It was therefore difficult to find men who were prepared to take their families to live in these remote regions. The topography of Sweden was such that the rivers had heavy flows and the falls were not generally well defined. To alleviate the problem of finding personnel, several plants were often constructed within a short distance of each other and it was therefore more practical to control such plants from one centre where either a community was already established, or where one could be built up.

A typical installation to illustrate the benefits of remote control is that at Kilforsen, where there are three plants within about seven miles of each other. At Kilforsen itself there are three generators, each of 95,000 kVA, at Lasele there are two 70,000 kVA units and at Långbjörn there are two generators of 45,000 kVA capacity each.

If the latter two stations were locally controlled the total personnel required would be 15, but with remote control only 9 men are necessary, and the operating staff for the whole group of three stations is limited to 18 men, comprising 2 superintendents, 12 control engineers, 2 electrical fitters, and 2 mechanical fitters; in addition, 9 men are needed for the outstations away from the Kilforsen central control point. The cost of housing labour for local control would be 430,000 S.Kr., while the investment in remote control equipment is 1,090,000 S.Kr. The annual costs are 420,000 S.Kr. for local control and 370,000 S.Kr. for remote control.

Dealing with the technical features of remote control, the authors stated that in most cases selector systems combined with a.c. cable transmission or radio links were used. It was a general requirement that it must never be possible for a false order or indication to be provided by the system itself. This made it necessary to have a supervisory circuit and a continuous current was transmitted over the system for this purpose. Unlike practice in other countries, lines for remote control were not rented from the public telephone authority but were provided and maintained by Board's engineers. Well-balanced regular four-wire cables, with phantom circuits, are usually installed, but if the cost is prohibitive radio links are used.

When radio links are employed, the circuit is designed for a high margin of fading, and in addition the equipment is duplicated to obtain the highest possible reliability. This duplication is carried out in two ways. The direct-current control impulses are fed to two tone transmitters in parallel, operating on different radio circuits. On the receiving side, there are two independent radio receivers and two tone receivers. The frequencies used are in the 70, 160 and 400 Mc/s bands. In one case there is a 10 km. television circuit in which the remote control point has a receiver connected to a camera supervising the dam, the gates and the switch yard, and is so arranged that it can be swung through 340° and tilted to $\pm 45°$.

On the question of reliability, statistics were given for a substation with a selector system and a single

radio link. It has been in service since January 1st, 1955, and on average there has been one fault every three months. The authors also discussed the possibility as to whether there was a limit to the number of power stations that could be remotely controlled from one centre without increasing the staff needed. Another point was the organisation of load dispatches involving the problem of whether load dispatching ought to be completely centralised for the whole power system, using remote control equipment, or whether it should be divided into smaller regions each dealing with the plants of one or more rivers and with a central headquarters to co-ordinate operations. This paper will be of great interest and benefit to those engaged in this type of work.

A new section, dealing with capacitors, was added to the CIGRE Conference this year. This session will doubtless grow in importance with the increased use of series capacitors for the regulation of power systems, and their application to the provision of reactive power at centres of consumption. However, the first meeting dealt mainly with the manufacture of capacitors, although there was some discussion as to the location of capacitor banks on various types of network.

A considerable part of the CIGRE session on cables was devoted to submarine cable problems. The use of high-voltage direct-current for submarine cable is now becoming general practice. The Gotland scheme has been operated successfully for four years, while the experience gained on the high-voltage d.c. land-laid cables between Kashira and Moscow, and the decision to use direct current for the 38-mile cable soon to be laid across the English Channel have contributed to the acceptance of this method.

There were four contenders for the best type of cable for use on submarine crossings. The flat cable, with oil pressure controlled by a special springy compensating device along its length, has been successfully laid on a number of occasions in Danish waters for voltages up to 132 kV. In some cases the floating drum method has been employed. Enfield Cables Limited have now commenced manufacture of this type of cable in Great Britain, and a paper from Messrs. C. T. W. Sutton and A. M. Morgan, of this firm, in conjunction with Mr. Møllerhøj, the Danish inventor, showed that a design suitable for direct current had been evolved, using two cores instead of three.

There was also a proposal from Great Britain, put forward in a paper by Messrs. R. C. Mildner and E. D. Humphries of the Telegraph Construction and Maintenance Company, for the use of plastic-insulated cables, which had now been developed so that operation at 200 kV to ground was a perfectly feasible voltage.

The merits of continuous manufacture were put forward in the discussion by Mr. E. L. Davey, of British Insulated Callenders Cables. He said that, for submarine use, the absence of joints was an overriding advantage. It was also possible to make the pressure pre-impregnated paper cable by using gas pressure over continuous lengths, and to make long lengths of the solid-type paper-impregnated cable. He agreed that where great depths were involved, it would probably be necessary to employ a plastic cable. Contributors from the British and French electricity supply authorities, who were jointly concerned in the Channel Cable Project, agreed on the use of the solid-type paper-insulated cable for the present. Their views were supported by the data given in an exhaustive paper by Dr. Gorodetzky, U.S.S.R., who gave detailed results of five years' experience with d.c. cables, and concluded that the solid-type cables were perfectly satisfactory providing certain design features were taken into account; for example, cables intended for direct current should have thinner and more dense paper tapes near the conductor and near the lead sheath. He thought cables of this kind would be suitable for use up to 400 kV.

In regard to cables for high a.c. voltages, it appeared from the discussion that the limiting voltage was likely to be 500 to 600 kV, due to the physical limitation which arose when the voltage gradient near the conductor was increased to too high a level. The dielectric losses also formed a limiting factor, while the equipment in cable factories appeared to limit the size of conductor to about 1,000 mm^2.

System stability is a subject with which CIGRE has always been particularly concerned. The conference has performed a useful function ever since its inception in 1922 by assembling valuable comparative data on the behaviour of various types of network. The use of series capacitors is growing and the special reporter of this section, M. Robert, said that there were at least ten such installations either in service or in course of construction. During the discussion, delegates from Sweden, Russia, Morocco and Japan spoke of the generally satisfactory results obtained with these devices. The discussion then turned to the possibility of improving stability by using fast-operating voltage regulators. It showed that there was still a need for greater co-operation between the regulator manufacturers and the network operation engineers.

There was some divergence of view as to which was the best type of network analyser. A number of papers referred to this subject, and one in particular, from Manchester College of Technology, by Messrs. C. Adamson and A. M. El Serafi, showed that British thought in this respect is taking a lead in regard to the problem of forecasting system stability. The paper suggested how equipment might be designed to give complete simulation of the transient characteristics of a synchronous generator and its regulator, and to be operated as part of a network analyser.

The use of automatic load control is obviously growing and a joint paper from French and German engineers showed that Electricité de France and the Rheinische-Westfalische Elektrizitätswerk A.G. systems could be operated in parallel with perfectly satisfactory results, both thermal and hydro stations taking part in the work of load exchange and frequency control. This experiment, involving 10,000 MW of plant on the French side and 15,000 MW on the German side, obviously points the way to greater European electrical integration.

The opinions given during the session on extra-high-voltage developments showed that the incidence of nuclear power generation would increase rather than reduce the need for the vigorous exploitation of water-power sources and for the utilisation of fewer transmission links. In the general discussion, under the chairmanship of Mr. Philip Sporn, of the Pacific Gas and Electric Corporation, it was seen that water

power was the ideal partner for nuclear power generation. Although much has been said and written about nuclear power, Great Britain is the only country which has a nuclear power programme of any real size in relation to its total generating resources.

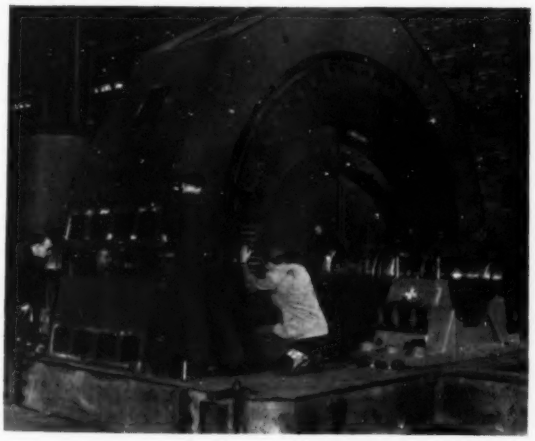
Russian engineers attending the congress showed that they have obtained a 15% increase of transmitted power on lines designed for 400 kV to 500 kV. Mr. F. J. Lane, of Preece, Cardew and Rider, consulting engineers, of Great Britain, warned that increased use of ugly transmission towers, growing taller as the voltage increases, might offend public opinion. He thought that it would be most desirable for engineers concerned with power transmission to concentrate on making more use of existing lines and routes. He said that single-circuit constructions did not make maximum use of the wayleave, and he felt that by paying even greater attention to the reduction of internal overvoltages, it would be possible to utilise higher voltages on existing lines and thus improve transmission capacity. He thought also that methods of insulation might well be fundamentally reviewed. The standard cap and pin insulator used in so many countries was not necessarily the final answer.

The delegates to this year's CIGRE Conference had the opportunity of making a number of technical visits, and one of the most interesting was an inspection of the newly-commissioned Plessis-Gassot substation, forming the Paris end of the first 380 kV line in use in France. This links the Gennissiat station on the Rhône and the other hydro stations in that area with the thermal stations in the north of France, enabling both types of generating equipment to be operated to better advantage. A feature of special interest in this substation was the use of suspended type circuit-breakers, made by Ateliers de Constructions Electriques de Delle, which were used for the first time at 380 kV, with a rupturing capacity of 12,000 MVA.

CIGRE, 1958, showed once again that the demand for electrical power throughout the world is increasing at an average rate of 7% per annum, and is thus doubling approximately every ten years. There was no indication of a drop in this rate of increase, in spite of economic problems or political considerations. There was also a clear indication that every country intended to develop to the full its natural resources of hydro-electric energy.

The Shin Scheme, Scotland

The Shin scheme of the North of Scotland Hydro-Electric Board is designed to produce power from the same water in a series of stations between Cassley in the remote mountains of Sutherland and the sea. The main contract for the generating and transformer equipment has been entrusted to Bruce Peebles & Co. Ltd., and our illustration shows the first of two



horizontal 12 MW generators for the lowest and main power station at Inveran (Shin). Along with them will go a 25 MVA Bruce-Peebles transformer.

The scheme will draw water from a catchment area of 509 square miles. At Cassley a 28 ft. dam will divert water from the River Cassley into a two-and-a-half-mile tunnel down to the head of Loch Shin, where two further Bruce Peebles generators, one of 325 kW and one of 125 kW, will be installed.

Typical of the wild desolate country is the fact that the engineers had to build five miles of road round a marsh to reach Cassley and that in the process they discovered remains of pre-historic trees.

Near Lairg the main dam across Loch Shin will raise the water 30 ft. Into this dam has been built a power station in which will be installed a 3·5 MW slow-speed generating set. The generator is 19 ft. in diameter and has a 29 ton rotor of the umbrella type. The stator, which weighs 25 tons, had to be taken north in two parts because of its size.

A third dam across the River Shin will divert water into a five-mile tunnel down to the main power station. As the water enters this tunnel it will drive a 100 kW induction generator by the same makers.

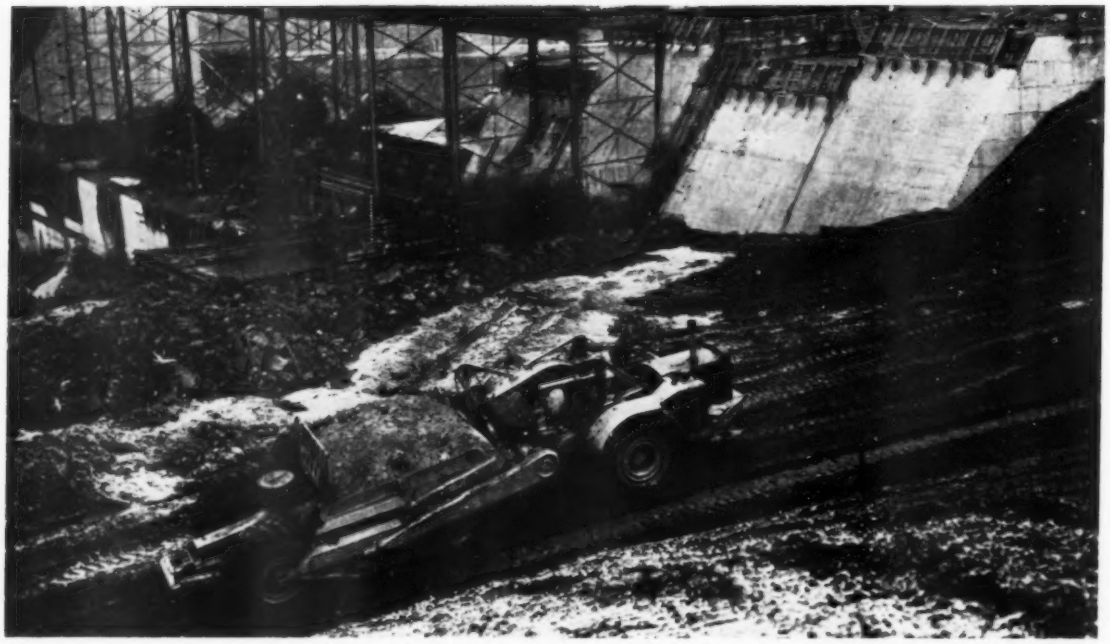
New Rawlplug Drill

The Rawlplug Co. Ltd. have introduced an entirely new electric drilling machine which has been designed to combine an intense rate of vibratory action with a fast rotary movement. It is stated to be especially suitable for drilling holes in all classes of concrete and to achieve a rapid rate of penetration through pebble aggregates. In addition to concrete, clean holes can be drilled quickly in granite, stone, engineering and blue bricks, quarry tiles, etc.

The "Vibroto" drilling machine, as it is called, is made up from two main units; a portable electric drill motor and gearbox unit, and a vibrating head which is clamped to the motor unit. Selection of force and speed of vibration to suit the material being drilled is obtained by turning a knurled ring which locks into position by a leaf spring fitting into the slots in the ring. The three positions cover respectively (a) rotary movement only; (b) light rapid vibrations; (c) heavy slow vibrations. The trigger switch can be locked into position if required for continuous drilling.

The weight of the machine is 9¾ lb., overall length 18½ in., chuck speed 940 r.p.m., voltages 230/250 and consumption 310 W. The drilling speed is dependent on the type of material penetrated but it is claimed that holes of No. 6 to 20 size can be drilled with a speed hitherto regarded as impossible.

Earth-Moving at Noxon Rapids

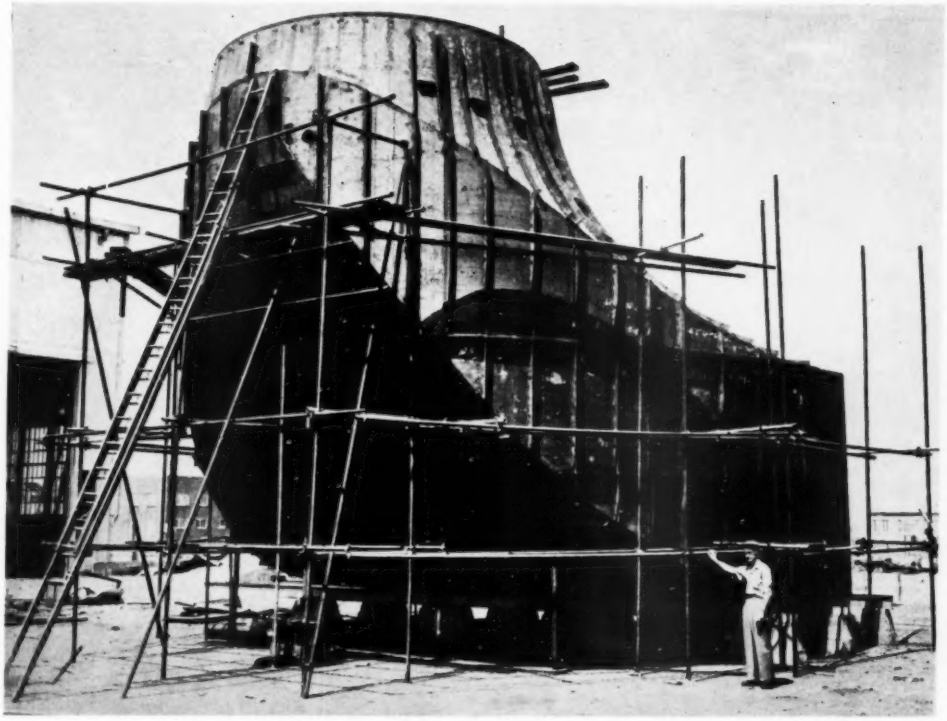


At the Noxon Rapids hydro-electric project on the Clark-Fork river, Montana, the dam has a maximum height of 265 ft. above bedrock and consists of a concrete central portion containing the power house and spillway flanked by earthfill embankments, the whole having a total length of 5,930 ft. Ultimately, the power house will contain five 137,000 h.p. generator sets having a total capacity of 500 MW. The reservoir will extend some 38 miles upstream and have a maximum storage capacity of 380,000 acre-ft. The project is being built by the Washington Water Power Company and is estimated to cost some £31 million.

The two earthfill embankments will require about two million cu. yards of material, all of which is being moved by equipment manufactured by the Caterpillar Tractor Co. Ltd. On the south-west embankment, which is the longer of the two, 300,000 cu. yards of clay will be required and this is being handled by six tractor scrapers working two 10-hour shifts. Side boards were affixed for the one-mile haul between the borrow pit and the embankment and each machine averages about five cycles per hour. On the fill itself two D8's are used to level the material, the required 95–100% compaction being achieved by the D8 machines and a sheepfoot roller. At the base of this embankment some sand and gravel had to be excavated to make way for the clay core which is carried down to the natural clay strata. While the clayfill is being placed, two Caterpillar No. 90 scrapers towed by D8 crawler tractors have been making short hauls, averaging 600 ft., to dump filter sand on both sides of the clay core. The embankment will require a total of 250,000 cu. yards of filter sand. Simultaneously with these operations, four DW21 wheel tractors with Athey PR21 rock wagons are being used to haul rock for the transition between the south-west earth embankment and the south-west end of the concrete portion of the dam.

In the rock quarry, drilling is being done with a Gardner Denver compressor and drill mounted on a D8 tractor. A Northwest Model 6 shovel, powered by a D13000 diesel engine, and a 44B Bucyrus Erie 2-yard shovel are loading out 20 pay yards into each wagon. The DW21–PR21 units are averaging three trips each per hour. The haul distance from the quarry to the transition is one mile.

Kariba Draft Tube Lining



The first draft tube liner for the Kariba hydro-electric power station, supplied by Boving & Co. Ltd., and assembled at Babcock & Wilcox, Vereeniging Works, has been delivered to site ahead of schedule. Construction of the 140,000 h.p. Francis turbines for this large underground power station has also begun. The Federal Power Board have ordered a sixth turbine from Boving, making a total of 840,000 h.p., to complete the first part of the installation for this important project.

Submarine Power Cable

In March, 1956, the BICC Group were instructed to investigate the practicability of linking the rich electric power resources of New Zealand's South Island with the supply network of the industrial North Island. This investigation resulted in an announcement on Monday, April 28, 1958, by Mr. H. Watt, the Minister in Charge of the New Zealand State Hydro-Electric Department, that the BICC Group are to lay, test and recover a trial length of cable in order to provide data for the ultimate installation of a submarine power cable across Cook Strait.

The trial cable, half a mile in length and with an overall diameter of 5 in., was manufactured at the Trafford Park Works of British Insulated Callender's (Submarine Cables) Limited; it is of the single-core pre-impregnated high-pressure gas-filled type, and is to operate at 250,000 volts d.c. It has a hollow copper conductor, is paper insulated and lead sheathed, and is suitably reinforced with steel tapes and steel wire armouring to withstand the particular conditions of the sea bed under Cook Strait.

This trial cable was not of sufficient length to warrant transport by a cable-ship as would be the case for the continuous length required for the complete crossing. The cable was coiled on a giant drum, believed to be the largest ever produced. This drum was 15 ft. 8 in. in diameter and 7 ft. 6 in. across, and, with the cable, weighed about 45 tons. It left Trafford Park Works on February 24, was loaded aboard the s.s. *Carronpark* at Liverpool, and arrived in Wellington, New Zealand, on April 16.

Under the supervision of engineers from British Insulated Callender's Construction Company Limited,

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—piston or rotary—delivers so much air for its size and weight

Compare the difference in size between the VT4 and an average rotary compressor in the 125 c.f.m. range.
125 cfm
150 c.f.m
Atlas Copco

PACKAGED POWER IN THE ATLAS COPCO VT4— THE WORLD'S LIGHTEST 150 c.f.m. COMPRESSOR

The VT4 is over 20% lighter and 25% smaller per c.f.m than any machine, piston or rotary, in its range.

Lighter and smaller than some machines with a free air delivery of only 60 c.f.m.—the VT4 has taken power weight ratios into a new dimension.

Powered by a Deutz diesel engine the VT4 gives an unequalled c.f.m./h.p. ratio, with fuel economies which offer a saving on any contract.

The VT4 is the first of a series based on major changes in design and production methods. For example, it is the only machine with a single welded unit, which incorporates the crankcase, bellhousing and cylinder ducting.

Basic simplicity in design eliminates maintenance and overhaul problems—local mechanics anywhere can service this machine.

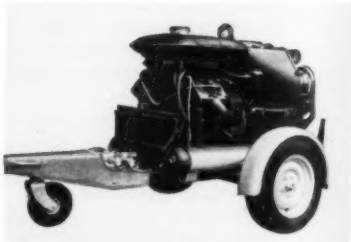
Unscrew one nut and all four valves in the low pressure cylinder can be removed. Loosen three bolts and the complete engine-compressor unit lifts out.

The VT4 is 100% air-cooled—starts on the button and works with equal efficiency anywhere in the world.

The VT4 is easier to load with its low weight and built-in lifting eye—easier to tow with its two wheels and torsion bar suspension.

Manhandling on site is a simple operation with a machine weighing less than 21 cwt. and fitted with a pivoting nose wheel.

All instruments and controls are operated from a central dashboard.



The VT4 is compactly assembled under a canopy which can be completely stripped in a few minutes to give maximum access.

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P.36

the trial length will be laid by the New Zealand Post and Telegraph Department's cable-ship HMTS *Matai* seawards from Oteranga Bay, which is on the North Island shore of Cook Strait south of Cape Terawhiti. After the ends have been sealed, the cable will be anchored and allowed to remain on the sea bed for as long as possible.

For the full-length cable the projected Cook Strait crossing route is a distance of some 25 miles, with a maximum depth of 150 fathoms.

Abstracts from the World Technical Press

Roxburgh Power Project, N.Z.

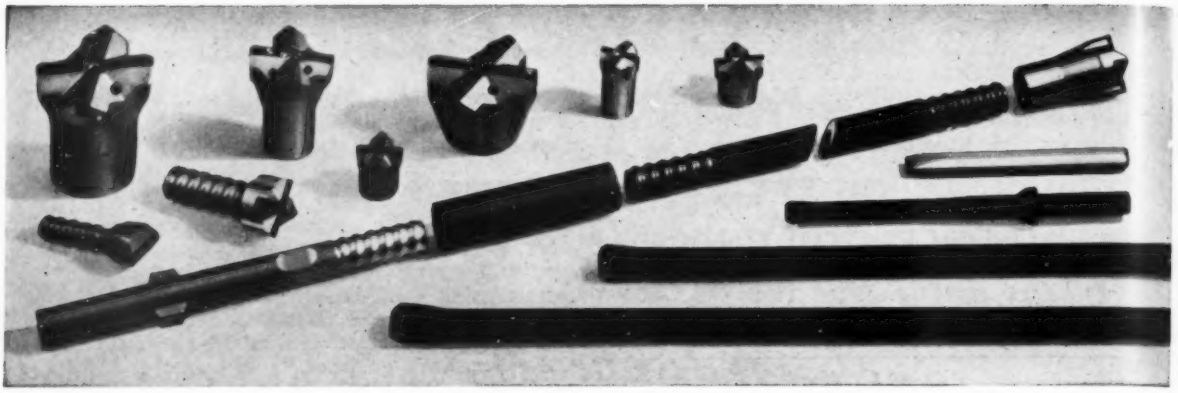
This paper deals specifically with civil-engineering design aspects of the Roxburgh power project on the Clutha river. The main features are a mass concrete gravity dam, 1,170 ft. long and 185 ft. high (240 ft. to lowest concrete in river gullet), constructed in 50 ft. wide monoliths, and structurally independent of the dam. The power house is 500 ft. by 100 ft. and 120 ft. in height from foundation to roof. The substructure housing the eight 56,000 h.p. Francis turbines and generators accounts for about half this height, while the power-house superstructure, 64 ft. wide, accounts for the remainder. After dealing briefly with investigations and alternative proposals, various facets of the design of the spillway and sluice block, diversion channel and power house are described, and some notes are included on the preparation of contract documents for the work. Hydraulic model tests, and details of specification, quantities and costs, are given in appendices. The civil-engineering layout for the project, including design of penstocks, intake gates, spillway gates and stoplogs, was carried out in the Hydro Design Office of the Ministry of Works, while the State Hydro-electric Department was responsible for the electrical design of the station. (C. H. Elam, Senior Designing Engineer, Ministry of Works, Wellington, *New Zealand Engineering*, Vol. 12, December 15, 1957, p. 408, 12 pp., 12 ff.)

Kurobe Dam No. 4

This concrete domed-arch structure now under construction for The Kansai Power Co., Osaka, Japan, which is to be the uppermost stage of the Kurobe river system, will add 258 MW capacity to the 241 MW already installed in four downstream plants. From a total catchment of 304 sq. km. Dam No. 4 on the Kurobe will drain no more than 80 sq. km. The central spillway will pass a flood of 35,000 cusecs, and the dam will be 1,240 ft. long at the crest. A pressure tunnel, six miles long and 10 ft. in diameter will feed an underground power house equipped with three 86,000 kW generators driven by six-nozzle Pelton turbines operating at an effective head of 1,840 ft. Apart from awkward problems of accessibility, the Kurobe river is ideal for hydro development Although a mere 53 miles in length, it falls to the Sea of Japan on an average gradient of 2·5%. The total drainage area is 304 sq. km. and has an average rainfall of 150 in. per annum. To mention but one of the construction difficulties, contractors had to build an access road 16 miles in length, and this required 3·4 miles of tunnelling. After two years of work, the road is now just nearing completion. The construction plant at the site is expected to be ready for service this year. Initial power is scheduled for 1960. The most conspicuous feature of the dam, which was designed by Electroconsult, Milan, under Ing. Carlo Semenza's guidance, is its height of 630 ft., which makes it the fourth highest domed-arch dam in the world. (*Engineering News-Record*, April 10, 1958, p. 55, 4 ff.)

Moesa-Calancasca Development

This article reproduces *in extenso* the lecture given at Chur by the author on March 14, 1958, before a joint meeting of the Rhine Association and the Grisons Association of Engineers and Architects. In addition to a historical survey of the various projects contemplated or carried into effect in the Mesocco region, it includes a detailed description of the first stage of new development on which work started in July 1957. The Moesa and its right-bank tributary, the Calancasca, flow in their upper and middle course roughly parallel to the Italian border, the Calancasca meeting the Moesa at about the point at which the latter turns westwards to join the Ticino river north of Bellinzona. The main work of the scheme is the 28 million cu. m. Curciusa reservoir, formed 2,164·5 m. above sea level by an arched gravity dam set up across the upper course of the Areuabach, a tributary of the Hinterrhein. This involves, in fact, the uncommon feature of a diversion of waters from the Rhine watershed into the Po watershed. In addition to the Areuabach, its tributaries of the Val Rossa, and the Val Balniscio Torrent also feed the reservoir which stretches from north to south over a length of about 2 km., with a maximum width of 470 m. From the north end of the left bank a power conduit, consisting of a 5 km. pressure tunnel connecting with a 1,360 m. pressure shaft, drives the two turbines of the 56 MW Pian San Giacomo station. A tailwater tunnel conveys the discharge to the Corina balancing reservoir, south of the Spina underground plant. Two reservoirs of 6 million cu. m. capacity ensure the main supply of power water to the Isola reservoir, near S. Bernardino, on the upper Moesa, and the Valbella reservoir on the upper Calancasca. The Spina power plant houses a 20 MW generating set actuated from Isola and a 7,500 kW set actuated from Valbella. The discharge of both the Isola and Valbella turbines can either join the tailwater from S. Giacomo in the Soazza pressure tunnel or flow to the Corina balancing reservoir through a connecting tunnel. This ensures a greater elasticity in the working of the Isola, Valbella and Curciusa stages. The Soazza tunnel feeds the underground power station of the same name at Ara, on the Moesa, about halfway between Spina and Roveredo. The power house, 56 m. by 18 m. by 21 m. in height, is equipped, in addition to a service set, with two 40,000 kW generating sets each driven by



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two horizontal Pelton turbines. Pending the construction of the downstream plant at Roveredo, the discharge from the Ara turbines will discharge back into the Moesa. Subsequently, however, a syphon will be provided under the bed of the Moesa to convey the water to the 26,000 kW Roveredo power house. The five plants of the Moesa-Calancasca development, also called the Mesocco Group of Power Plants, control a catchment of 215 sq. km. and, with an aggregate installed capacity of 190,000 kW, will be able to produce a yearly average of 530,000 million kWh. The scheme will be operated by the Misoxer Kraftwerke AG in Mesocco, founded last year with the participation of the Grisons Canton, the Elektro-Watt AG in Zürich, and three other Swiss concerns. The construction has been planned in four stages: 1957 to 1960, Soazza and Isola plants; 1958 to 1961, Valbella plant; 1960 to 1965, Pian S. Giacomo plant and Curciusa reservoir, whereupon work on the Roveredo installations will begin. Roveredo was selected as the final stage of the whole development owing to the fact that the necessary geological investigations are still in progress, especially around the sites of the underground balancing reservoir and of the power house. Expenditure, based on the 1956 prices, is estimated at about 250 million Swiss francs (about £20 million). (A. Spaeni, Chief Engineer, Elektro-Watt AG., Zürich, *Wasser- und Energiewirtschaft*, No. 4, April 1958, p. 73, 15 pp., 15 ff.)

Synchronous Motors for Storage Pumps

This article describes in detail the two 12,000 kW Oerlikon synchronous motors which drive the two Sulzer storage pumps at the Peccia power station. These pumps lift the water from the Peccia surge reservoir and from the Corgello supply conduit to the Sambuco storage reservoir which is 1,461 m. above sea level. The stored water is then supplied in stages to the turbines at the Peccia, Cavergno and Verbano plants. The motor characteristics are: 12,000 kW continuous rating at 0·95 power factor, voltage 12,000 +9%–11%, rated current 625 A., normal speed 1,000 r.p.m., speed at reverse water flow 1,300 r.p.m., short-time rating 30 minutes, frequency 50 c.p.s. Efficiency at rated voltage, full load and unity power factor 97·8%, at 0·95 power factor 97·6%, at three-quarter load, 97·4% and 97·3% at unity and at 0·95 power factor respectively. (W. Borel, *Bulletin Oerlikon*, English Edition, No. 323, August 1957, p. 53, 8 pp., 10 ff.)

Victoria Water Resources

In the first of the three articles of this symposium, L. R. East deals with the "Development of a National Water Policy in Victoria" and K. D. Green, in the second, reviews the "Measurement and Evaluation of the Water Resources in Victoria," describes the present state of their exploitation, and assesses possible future developments. In the third paper, devoted to "Design, Construction and Operation," R. A. Horsfall gives a brief outline of the main sources of supply used in Victoria for irrigation and water-supply purposes. He describes the most important works associated with these developments and discusses aspects connected with the design, construction, operation and maintenance of reservoirs, dams, weirs and channel works, the design of drainage systems in large irrigation districts, and the Lake Corangamite Reclamation Scheme. (*The Journal of the Institution of Engineers, Australia*, January–February issue, 1958, p. 35, 30 pp., 27 ff.)

Flow Studies

This paper, which appears in French and English side by side, investigates the characteristics of flow in a small tilting channel, rectangular in cross-section, presenting a symmetrical lateral constriction in the form of sharp-edged plates fixed normally to the flow. The flow rate, Q, is related to the upstream depth y by means of a discharge equation $Q=Cby_1^{3/2}$, where b is the width of opening and C is an experimental coefficient which depends upon the constriction ratio and the Froude number of the unconstricted flow. The values of C are established for Froude numbers up to 2·1 and constriction ratios up to 95%. The conditions under which insertion of constriction plates produces an increase in upstream depth are examined and the extent of the increase is evaluated. (H. R. Vallentine, Senior Lecturer in Civil Engineering, N.S.W. University of Technology, Sydney, *La Houille Blanche*, Vol. XIII, No. 1, January–February 1958, p. 75, 10 pp., 7 ff.)

Pumped-Storage Plants in Winter Service

A detailed account is given of the experience gathered at the Reisach-Rabenleite plant during its first winter of service. It is equipped with two pumping sets, each driven by a 35 MVA generator and consuming 28 MW while pumping, and was put into commission in the autumn of 1955. During the cold spell of January and February 1956, when temperatures dropped as far as −35°C. in the Upper Palatinate, the plant and its storage facilities were subjected to uncommonly difficult conditions. The thickness of the ice in the reservoirs reached 45 cm. and at the Kainzmühl dam the strain of the ice layer was so strong that relief could only be obtained by sawing off a 56 cm. strip of ice parallel to the dam. This strip was prevented from freezing. In the pumped-storage reservoir on the Rabenleite, icing proved particularly inconvenient at the 1 : 2 inner slope of the bank enclosing the reservoir, the level of which sinks about 12 m. every day and is raised again by night pumping. With the repetition of this process ice blocks up to 3 m. high accumulated. When the thaw began the bottom blocks became loose and, during the afternoon, slipped into the reservoir (which was then at its lowest level), frequently damaging the bitumen joints of the floor. The strong ferro-concrete intake tower in the reservoir suffered no damage whatsoever but two of the trestles of the footbridge connecting the tower with the bank of the reservoir shifted under ice pressure and had to be replaced in the spring of 1956. At the same time, all other trestles had to be strengthened by welded angle sections. Icing at the banks of the Trausnitz reservoir caused no inconvenience but pack ice jammed the three sluice gates of the dam and measures had to be taken to thaw them. This was done from the downstream side by means of propane burners. Two days later, however, the frost broke and the resulting high water wave removed most of the ice from the gates and their seals. The increased temperature of the power water caused by its flow through the supply tunnel and the turbines

kept the reservoir in front of the embankment wall of the power house free from ice. A stoppage of one or two hours was enough to enable the ice to form anew but it broke again soon after the turbines had been restarted. At Reisach, operation of the power house was hardly affected by ice, and the siting of the strainers of the pumps and ancillary water services at a deep point of the embankment wall proved most favourable. The power-house oil-heating system was completely satisfactory, even during the coldest spells. In fact, while other water-power plants in the region had to reduce output during that period, Reisach never stopped operating at full capacity. Altogether the Reisach storage-pumping installations have stood the test of an uncommonly cold winter extremely well. Weak points in the system have been detected, and measures taken to limit stoppages in the future. (Hubert Kolb, *Die Wasserwirtschaft*, Vol. 48, No. 3, December 1957, pp. 63/64.)

Large Dams on the Tigris

Four dams in the upper reaches of the Tigris and its tributaries will intercept the bulk of the water and store it for beneficial use; two of them, now under construction, are described in this article. The Derbendi Khan, on the Diyala river, is being built by the Harza Engineering Company, and will be a rockfill structure 440 ft. high, 1,560 ft. long at the crest and 1,650 ft. wide at the base, giving a total volume of 9.2 million cu. yards. Two features distinguish the design—both its faces will be stepped in benches, and the spillway of the ogee overflow type, with chute and deflector bucket, will have a discharge capacity of 410,000 cusecs, i.e. nearly three times the maximum known flood at the site. The reason for this excessive capacity was the lack of any long-period flood records. The reservoir will have a volume of 2·5 million acre-ft., with enough dead storage capacity to accommodate the estimated silt deposits of 50 years. The stored control will be used for irrigation, flood control and power. A small initial installation of two 800 kW units operating under a 264 ft. net head will be made, with provision to develop 100,000 kW if needed. At Doka, on the Little Zab river, the impounding structure will be a concrete arch which will rise 381 ft. above the lowest foundation, have a crest length of 1,181 ft. and contain 476,500 cu. yards of concrete. The work was started three years ago and is scheduled for completion by 1960. The grouting of dam foundations and adjacent reservoir bottom required the drilling of 675,000 ft. of holes into which 46,500 tons of cement and 32,000 tons of sand were injected. There are two spillways through the rock of the left abutment, one bell mouthed and situated on the top of a vertical shaft 318 ft. deep. Five 12 ft. diameter penstocks embedded in the dam will serve a future 200 MW power station, the turbines of which will operate under a mean effective head of 260 ft. Dokan dam was designed by the London consulting firm of Binnie, Deacon and Gourley, and checked by a panel of international experts consisting of S. O. Harper, U.S., André Coyne, France, and H. D. Morgan, Great Britain. The main contractors are MM. Dumez-Ballot, of Paris. Of the two other dams planned, Bekhme dam on the Great Zab river would control about 25% of the total run-off of the upper Tigris, and Eski Mosul dam on the Tigris itself, about 50%. The construction of Bekhme dam, designed by the Harza Company as a massive buttress dam 613 ft. high and 2,700 ft. long at the crest, has been postponed for further studies. The dam being considered for Eski Mosul would be an earth and gravel fill, with a concrete spillway through the left abutment; it would be about 1·2 miles long and require 37 million cu. yd. of fill and 3·3 million cu. yd. of concrete. The site, about 25 miles upstream from the city of Mosul is now being core drilled by Harza Engineering Company. Work is not expected to start before 1960, which would place completion date in 1965. (Waldo G. Bowman, Editor, *Engineering News-Record*, Vol. 159, Dec. 26, 1957, p. 32, 6 pp., 12 ff.)

John Day Dam

The announcement by the Walla Walla District of the Corps of Engineers that bids on the first-step cofferdam for the John Day dam were to be called in June gave definite indication that this controversial Columbia river structure was to be begun at an early date. The cofferdam, which will enclose the navigation lock and part of the spillway section, will be run out from the Washington shore of the river. The power house on the Oregon side is to have an initial capacity of 1·2 million kW in twelve generating units, and studies are now being made to determine when further additional units will be needed. Subject to construction getting under way this year, as planned, first power is expected to go on the line in 1969. (*Engineering News-Record*, April 17, 1958, p. 24, 1 f.)

Cableway Towers Travelling on Tracks

Concreting of India's Rihand dam is now under way, using cable towers that travel on concrete platforms. Rihand will be a 296 ft. high concrete structure, 3,065 ft. in crest length, that will impound 8·6 million acre-ft. of water. The construction will require 2·25 million cu. yards of concrete and this will be placed by a 10 ton cableway in the bottom portions of the dam and two 20 ton cableways, spanning 3,100 ft., which will place the upper monoliths. The concrete mixing plant will have a capacity of 4,500 cu. yards a day from 4 cu. yard tilting mixers. (*Engineering News-Record*, May 1, 1958, p. 55, 1 f.)

Note. Cf. WATER POWER, June 1957, p. 237: Fabricated Blondin Runways.

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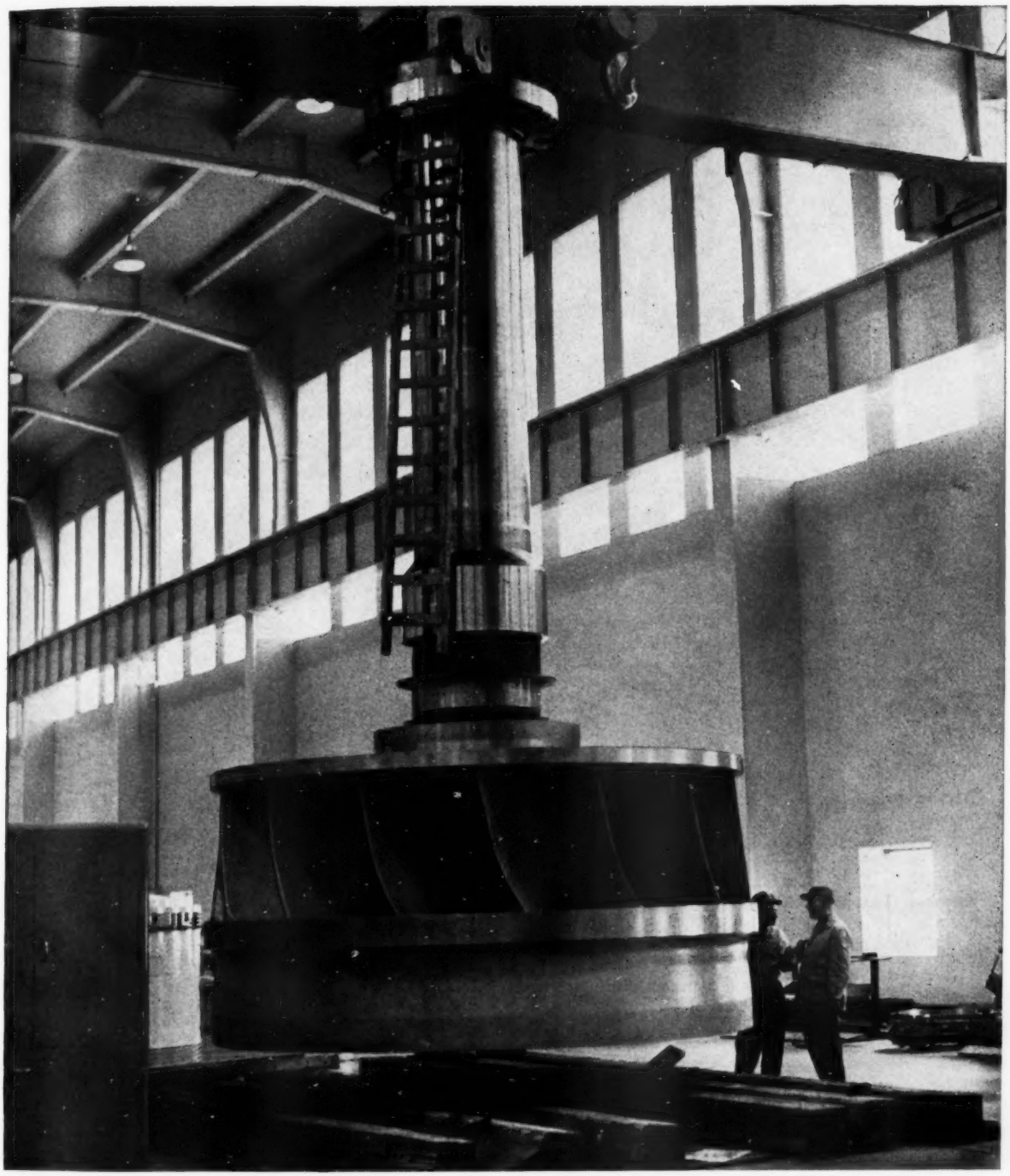

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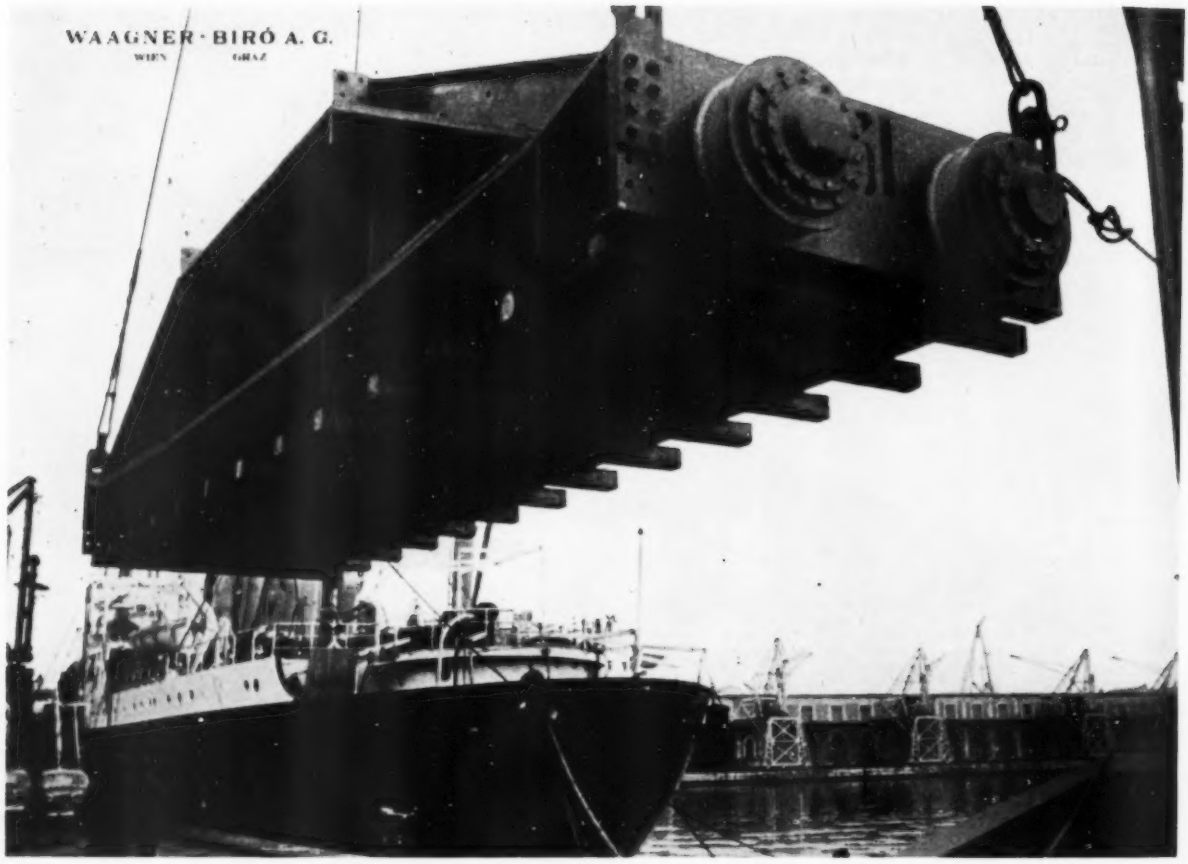

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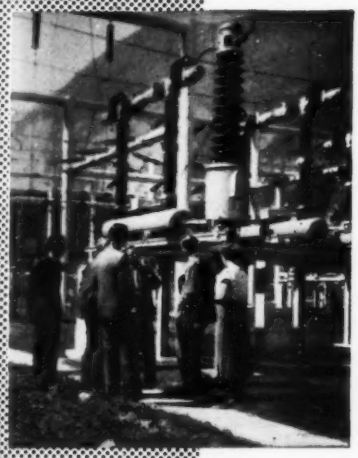

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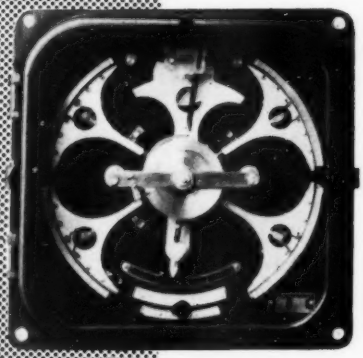

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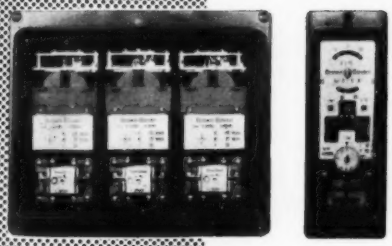

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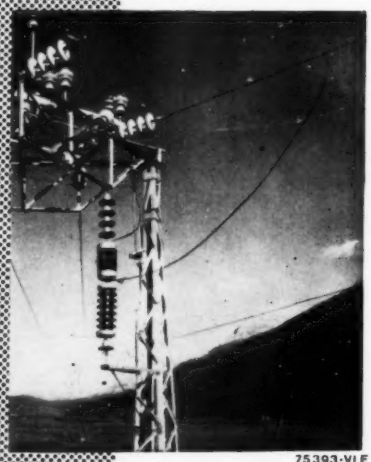

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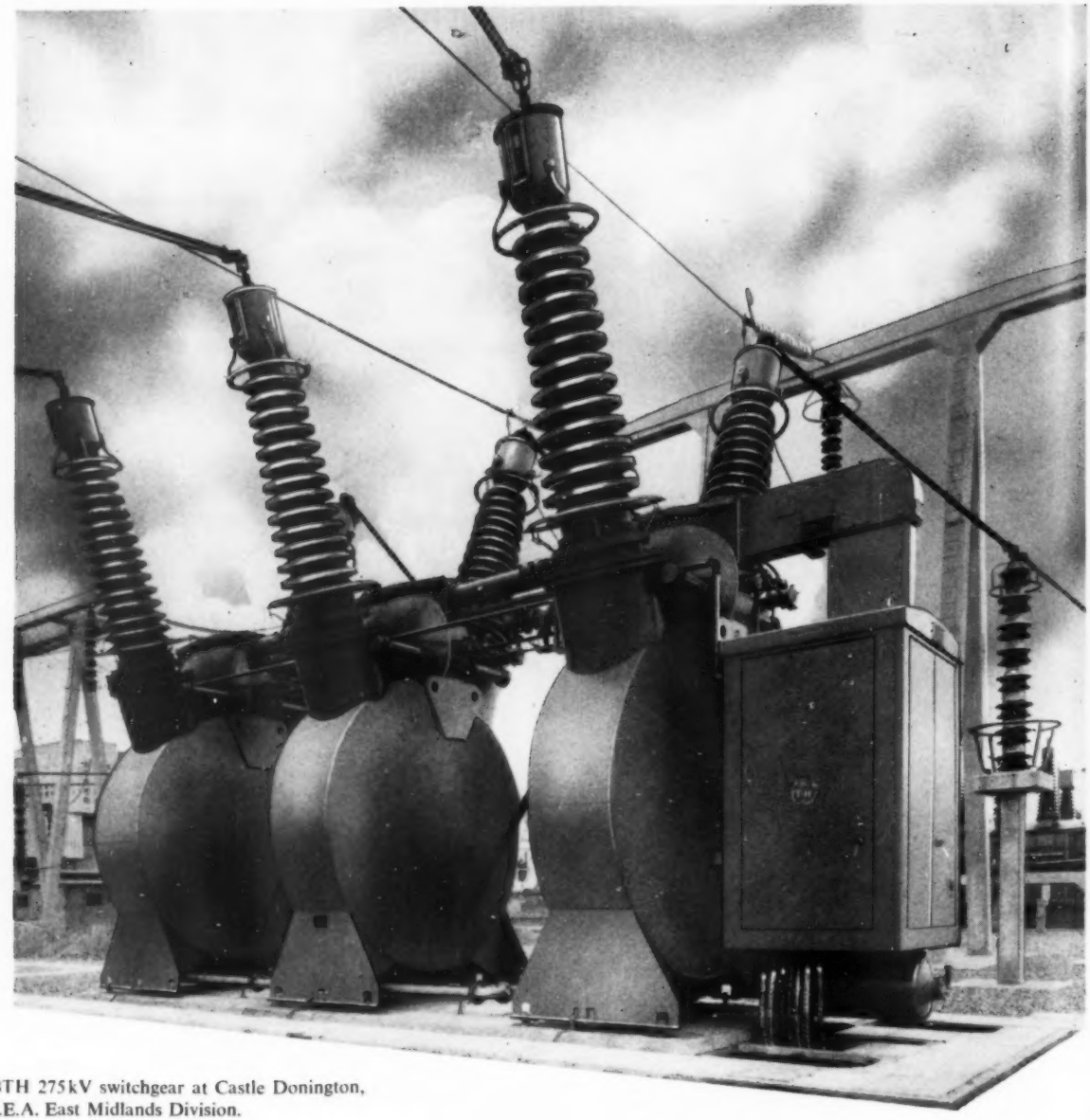

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THE GIORRA DAM

The 1,450 foot long and 100 foot high dam at the eastern end of Loch Giorra is an important part of the Killin Section of the North of Scotland Hydro-Electric Board's Breadalbane Power Scheme. Edmund Nuttall are the contractors for this work and the photograph shows the buttresses of the dam nearing completion.

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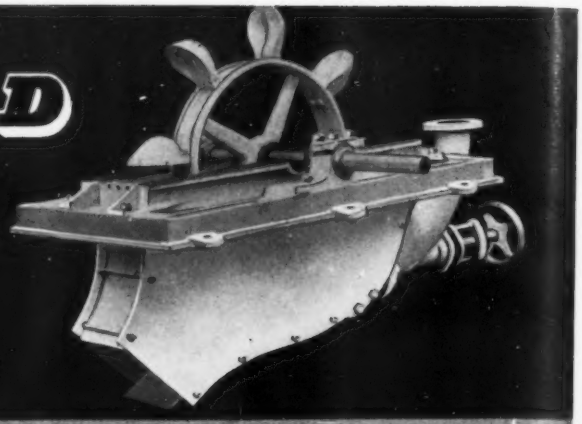

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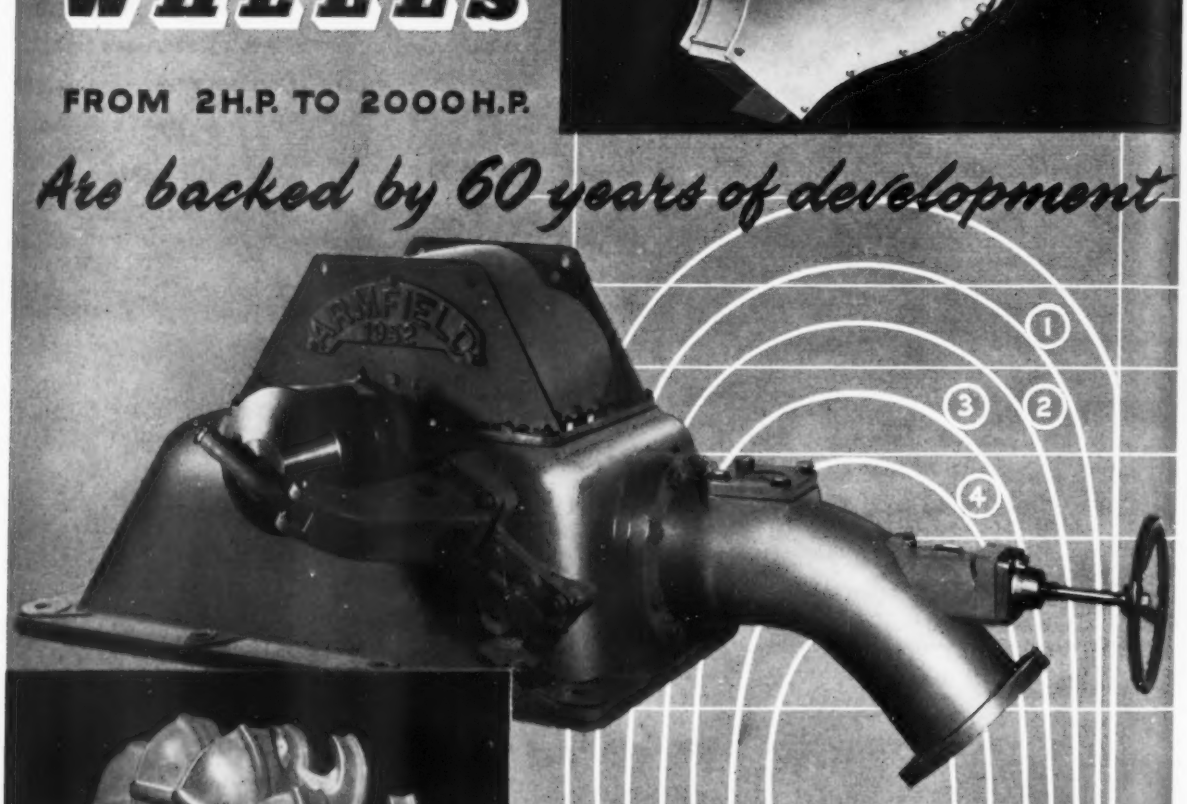

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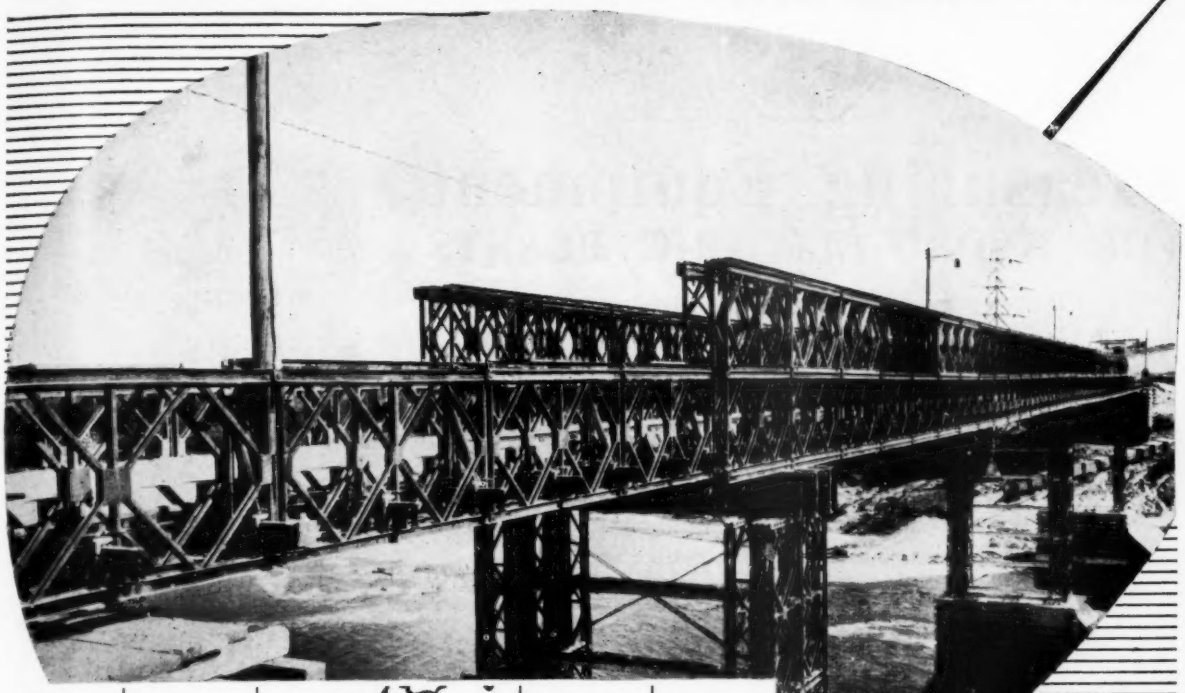

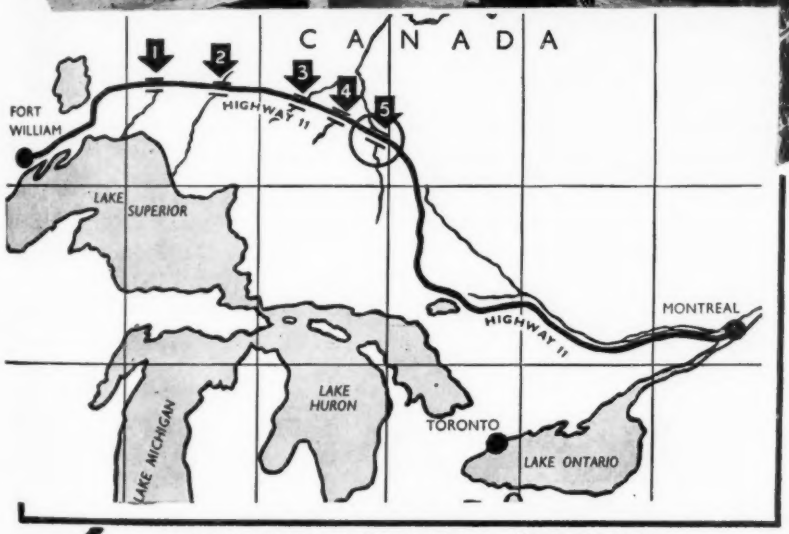

1. STEEL RIVER. 2. FRENCH RIVER. 3. LITTLE PIC RIVER.
4. KAPUSKANG RIVER. 5. MATTAGAMI RIVER.

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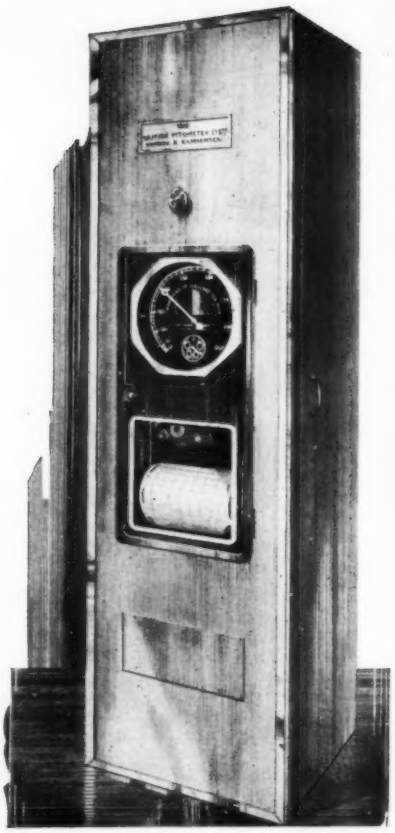

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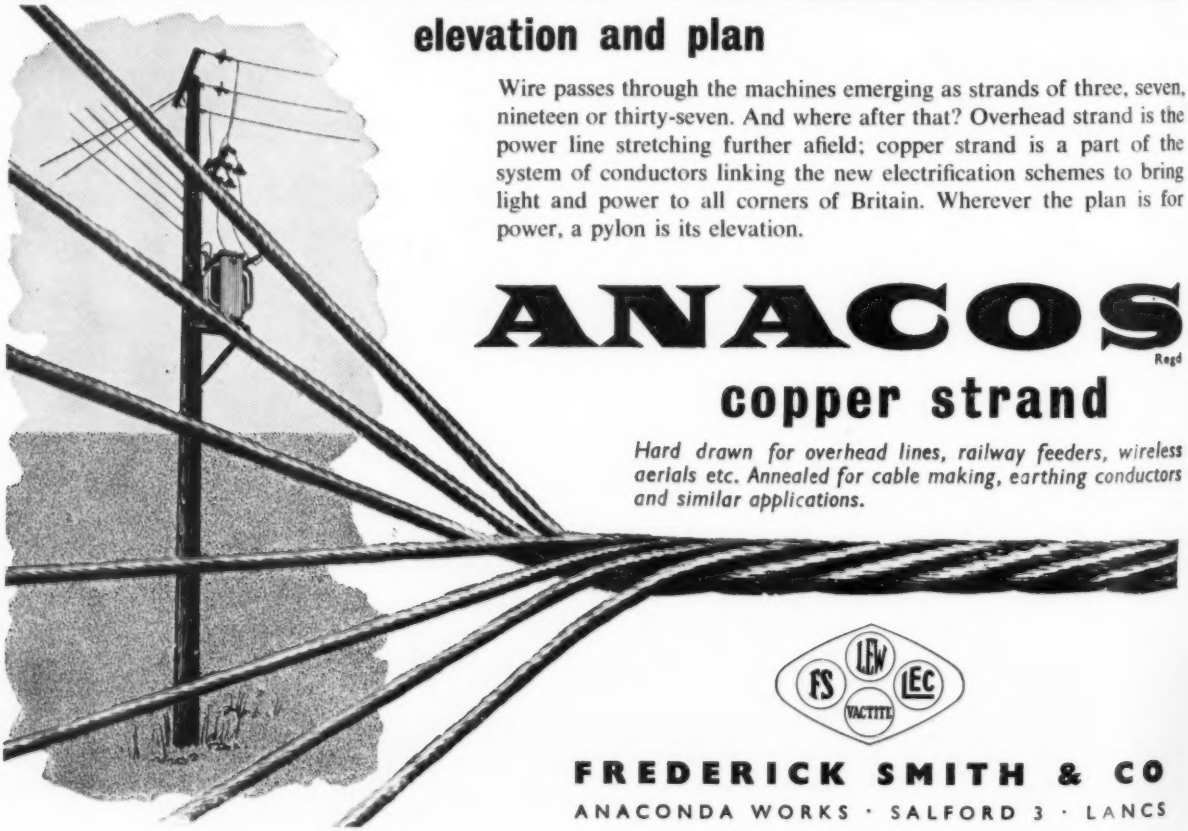

elevation and plan

Wire passes through the machines emerging as strands of three, seven, nineteen or thirty-seven. And where after that? Overhead strand is the power line stretching further afield; copper strand is a part of the system of conductors linking the new electrification schemes to bring light and power to all corners of Britain. Wherever the plan is for power, a pylon is its elevation.

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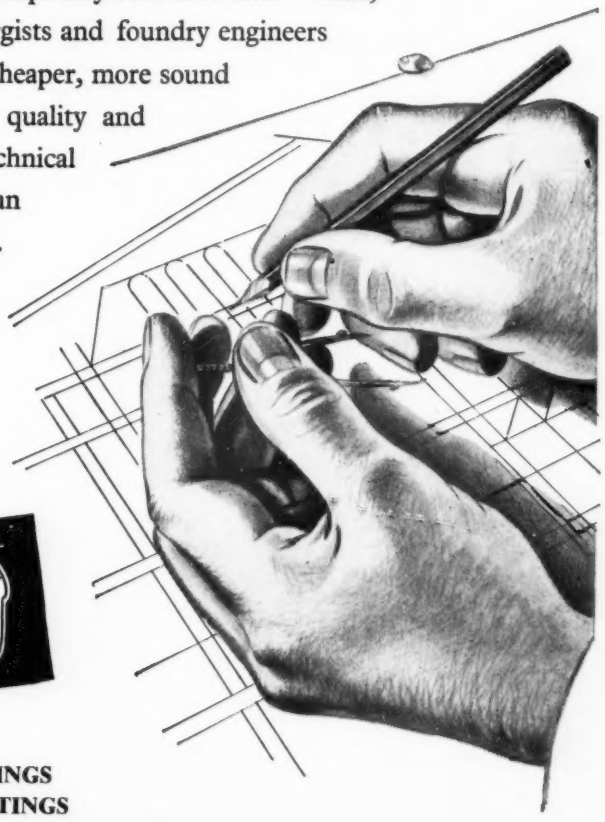

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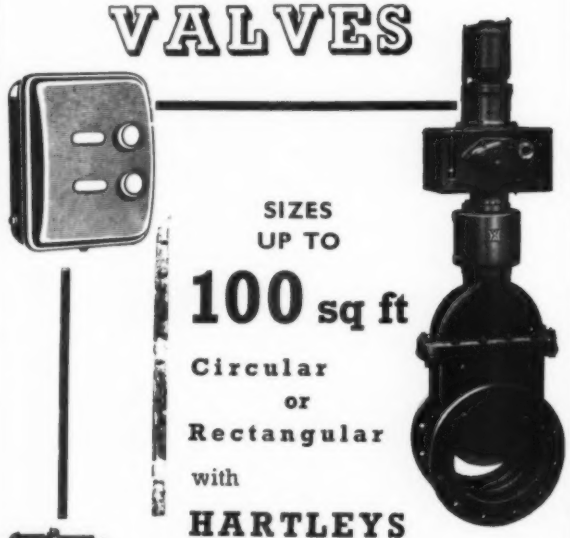

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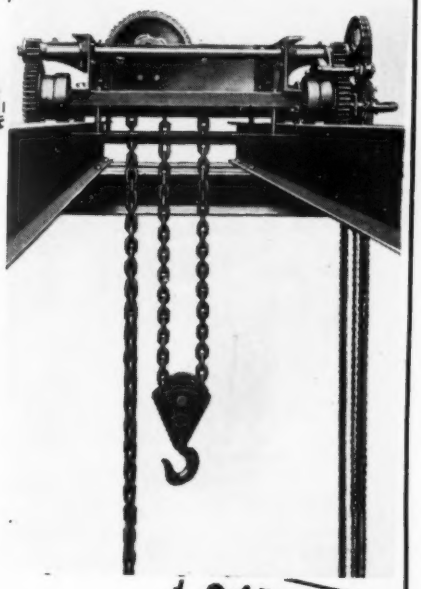

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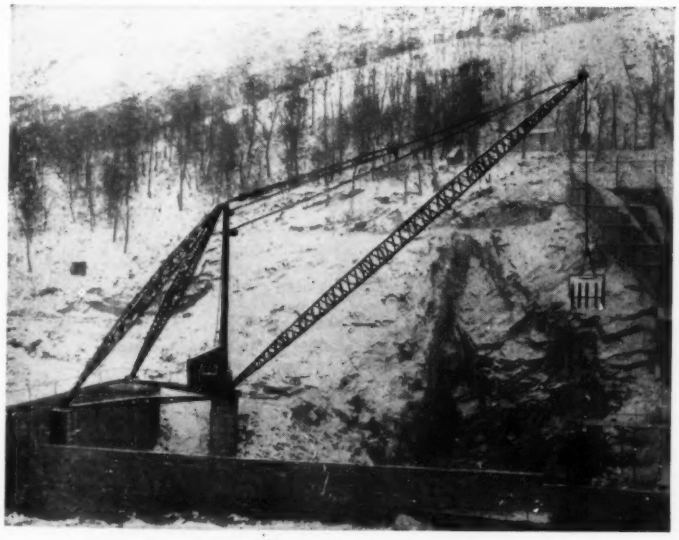

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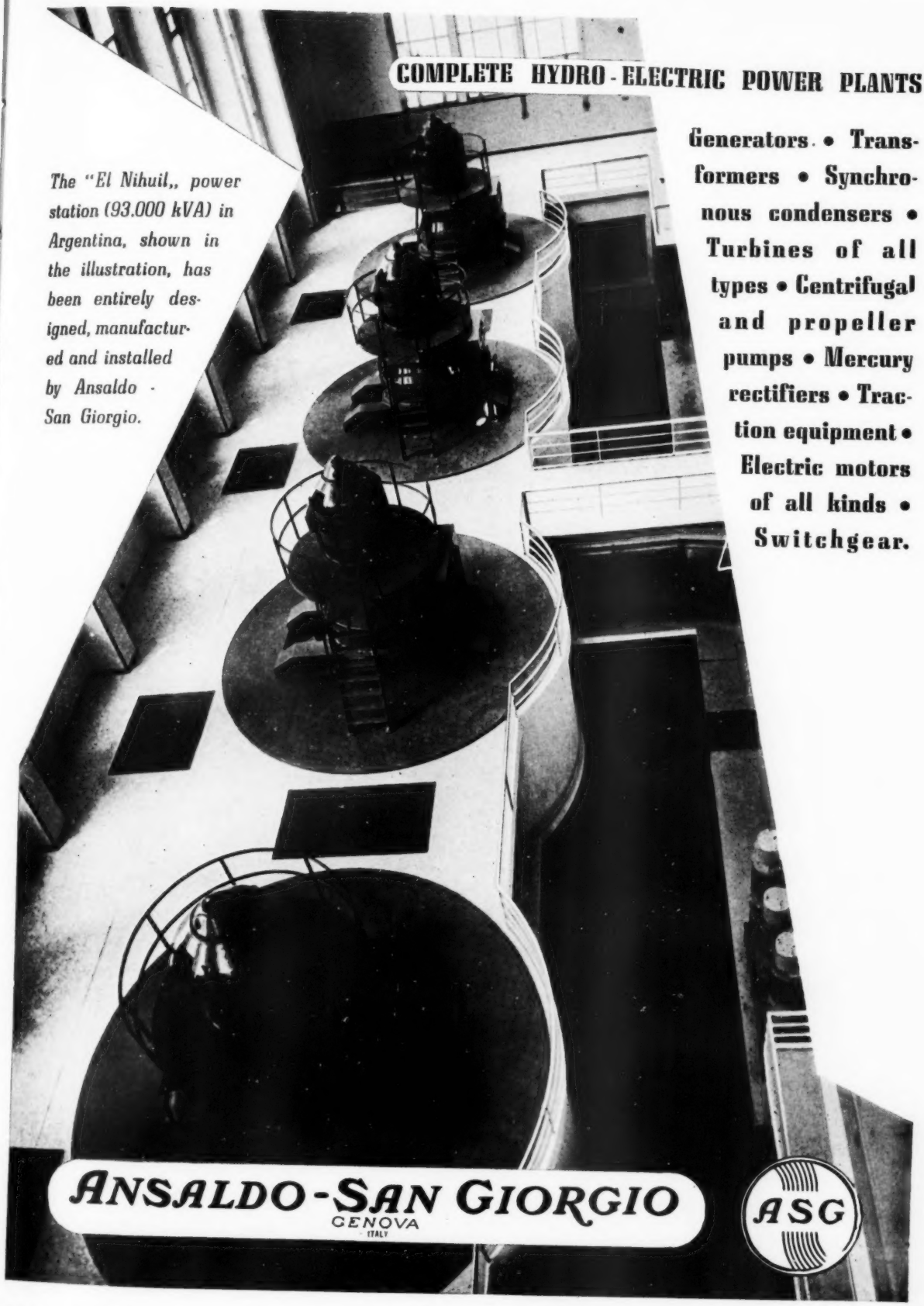

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